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Juvenile Salmonid Use of Created Stream Habitats Sammamish River, Washington 2001 Data Report

-FINAL-

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February 2002

1295.01

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EXECUTIVE SUMMARY

Habitat alteration and/or loss has contributed to large-scale declines in the number and geographic distribution of both resident and anadromous fish species inhabiting the Pacific Northwest. Until the passage of the Environmental Protection Act in 1970, many large federal, state, and locally authorized flood control, hydroelectric, and irrigation projects served to alter the fish habitat in numerous rivers and streams in the Puget Sound. The Sammamish River also suffers from years of extensive modifications of its instream and riparian habitats. The construction of the Lake Washington Ship Canal and Locks lowered Lake Washington approximately 9 feet and Lake Sammamish by nearly 6 feet and combined with dredging and channel maintenance projects, decreased the connectivity of the Sammamish River with its floodplain. Today municipalities, golf courses, a sewer pipeline, and the Sammamish River Trail, which is a popular recreation site for Redmond, Woodinville, and Bothell residents, border much of the river. Local sponsors have recently adopted a "multi-objective" management approach for the Sammamish River and have initiated the Lake Washington General Investigation Basin Restoration Study (GI) and several small-scale fish enhancement projects.

This study was initiated to compare juvenile use of mitigation and restoration sites in the Sammamish River to their use of natural habitats in the Sammamish River. Monitoring also quantified the time period that juvenile salmonids inhabit the Sammamish River. Nighttime juvenile salmonid use was monitored in 22 sites during the 2001 study period using backpack electrofishing methods modified for use on the Sammamish River. The first survey was conducted on 20 February, while the final survey was completed on 18 July. A total of 1,627 salmonids were captured during 2001 nighttime electrofishing surveys. The majority of the juvenile salmonids were coho (N=578; 36%), followed by sockeye (N=551; 34%), and chinook salmon (N=311; 19%). The remaining juvenile salmonids were composed of cutthroat (N=163; 10%), and rainbow trout (N=13; <1%), and mountain whitefish (N=11; <1%). Catch (all survey sites combined) of all juvenile salmonids (i.e., chinook, coho, and sockeye salmon, and rainbow and cutthroat trout) peaked in the Sammamish River during the week of 20 May, which also coincided with individual peak of chinook salmon. Catch rates of sockeye salmon fry peaked during the survey conducted on 19 March. Mean coho salmon capture indices increased steadily from the initial survey date through early May, decreasing from there until the last survey conducted on 18 July. The catch rates of rainbow and cutthroat trout in the Sammamish River remained fairly constant throughout the survey period. Mean juvenile salmonid catch was highest in Reach 1 and decreased in subsequent reaches of the river. Mean CPUE from Reach 1 was significantly greater than mean catch from Reach 2, Reach 3, and Reach 4. Reach 2 catch indices were greater than both Reach 3

and Reach 4, however, there was not significant differences in juvenile salmonid catch between the three remaining reaches.

A post-treatment experimental design was used to determine the response of juvenile salmonids to different enhancement/restoration techniques, whereby comparisons were made between test and control sites over time. These comparisons were replicated in different reaches of the Sammamish River. Juvenile salmonid catch indices were consistently greater than their associated control sites at sites containing setback levees without large woody debris. This difference was apparent at both the site level and between reaches. Juvenile salmonid catch indices from sites containing both large woody and a setback levee were also greater than their associated controls at all sites and on most survey dates. Juvenile salmonid use of large woody debris without setback levees was only examined at one location in the Sammamish River. Catch of juvenile salmonids from this site was greater than the control site; however the difference was not great enough to reject the possibility that the difference is due to random sampling variability. The importance of mainstem habitat for juvenile chinook salmon rearing and migration is becoming more evident throughout the Pacific Northwest. The Sammamish River lacks off-channel habitats, thus increasing the importance of mainstem habitat in this situation.

We found a mixed response of juvenile salmonids to current enhancement/restoration strategies utilized in the Sammamish River. Juvenile salmonids exhibited a preference for levee setback sites that did not contain large woody debris. Juvenile salmonid use of sites containing large woody debris sites, with and without levee setback, were significantly lower than within the levee setback sites without wood. The gradation between the three restoration/enhancement techniques indicate that the shallow bank angle had a greater influence on juvenile salmonid use than the presence of LWD. Even within the natural stream sections of the Sammamish River, juvenile salmonids were consistently found residing in the portions with the lowest bank angle. Water temperatures appear to limit the period that juvenile salmonids can safely reside in the Sammamish River beginning in late July. We recorded mean daily water temperatures exceeding 22ºC in the Sammamish River at Marymoor Park during this study. We recommend that stream enhancement/restoration activities concentrate their efforts in areas located immediately downstream from tributary inflow. Tributary inflow areas may also provide for the majority of spawning habitat in the Sammamish River. In this manner, habitat enhancement benefits would be provided to both juvenile salmonids outmigrating from tributaries and salmonids emerging from spawning locations in the Sammamish River. Finally, this study was developed to evaluate the response of juvenile salmonids to existing stream enhancement/restoration projects that are currently used in the Sammamish River. The response exhibited in the Sammamish River may not be indicative of responses found elsewhere in the Pacific Northwest.

1. INTRODUCTION

1.1 BACKGROUND

Habitat alteration and/or loss has contributed to large-scale declines in the number and geographic distribution of both resident and anadromous fish species inhabiting the Pacific Northwest (Nehlsen et al. 1991; Weitkamp et al. 1995; Hard et al. 1996; Busby et al. 1996; Johnson et al. 1997; Gustafson et al. 1997; Myers et al. 1998; Johnson et al. 1999). Until the passage of the Environmental Protection Act in 1970, many large federal, state, and locally authorized flood control, hydroelectric, and irrigation projects served to alter the fish habitat in numerous rivers and streams in the Puget Sound (Cramer et al. 1999). In Puget Sound, production capacity of juvenile coho salmon (*Oncorhynchus kisutch*) in summer and winter habitats were reduced by 24% and 34%, respectively (Beechie et al. 1994). Specifically, more than 70% of summer habitat and 90% of winter habitat losses were attributed to diking, ditching, and dredging efforts that were associated with urban- and agricultural-based land management activities on the Skagit River.

Like the Skagit and many other rivers in Puget Sound, the Sammamish River also suffers from years of extensive modifications of its instream and riparian habitats (King County SWMD 1993; Warner et al. 1999). The percentage of the total Sammamish River exposed to anthropological perturbations is greater than the Skagit River, and quite possibly any river of comparable size in Puget Sound, however. Beginning in 1916, the construction of the Lake Washington Ship Canal and Locks (Chittenden Locks) lowered Lake Washington approximately 9 feet and lowered Lake Sammamish by nearly 6 feet (Martz et al. 1999). Unlike in 1895, when the Sammamish River was free to meander across its floodplain, today municipalities, golf courses, a sewer pipeline, and the Sammamish River Trail, which is a popular recreation site for Redmond, Woodinville, and Bothell residents, border much of the river.

In response to regional declines in salmonid populations, the Sammamish River has been identified as a possible site of system-wide salmonid habitat restoration/enhancement measures. In years past, the primary management objective for the Sammamish River has been to confine the river channel and floodplain in an attempt to control flood waters (King County SWMD 1993). Under an agreement with the federal government, King County was required to conduct periodic removal of all vegetation greater than four inches diameter from stream banks, remove large woody debris from the channel, and periodically dredge "problem areas" (King County SWMD 1993; Warner et al. 1999). While meeting flood control objectives in most cases, these management practices have resulted in the impairment of aquatic habitats critical to survival of both resident and anadromous salmonids.

Local sponsors have recently adopted a "multi-objective" management approach for the Sammamish River and have initiated the Lake Washington General Investigation Basin Restoration Study (GI) and several small-scale fish enhancement projects (e.g., City of Redmond Riverwalk Project, King County DNR Remeander Project). Currently, little information is available on the periodicity and residency of juvenile salmonids in the Sammamish River. Malcom et al. (1996) conducted preliminary electrofishing surveys in the lower Sammamish River during 1996. Their study indicated chinook salmon (*O. tshawytscha*), coho salmon, sockeye salmon (*O. nerka*), rainbow trout (*O. mykiss*), and cutthroat trout (*O. clarki clarki*) are present in the Sammamish River downstream of Interstate 405 in May and July. A juvenile outmigrant trap, located near the mouth of Bear Creek, also provides some information of the timing of juvenile salmonid residence in the Sammamish River (D. Seiler, WDFW, pers. comm). Despite the above efforts, a quantitative study has not been conducted to determine the habitat type preferred by juvenile salmonids (especially chinook), a period of residency of juvenile salmonids, or a baseline for which adaptive management decisions can be made during the restoration process in the Sammamish River.

1.2 OBJECTIVES

A juvenile salmonid monitoring program was initiated in late May 2000 to compare juvenile use of mitigation and restoration sites in the Sammamish River (e.g., large woody debris) to their use of "natural habitats " in the Sammamish River. The study was funded through the U.S. Army Corps of Engineers General Investigations Program and conducted by R2 Resource Consultants. Juvenile salmonid surveys were conducted from 31 May through 1 August 2000. The study area encompassed 15 sites along the entire length of the Sammamish River from the outlet of Lake Sammamish, downstream to its confluence with Lake Washington. The pilot study was discontinued in August because elevated water temperatures increased risk of injury to captured salmonids. Preliminary study results indicated that juvenile salmonids exhibited a preference for different nearshore habitat types in the Sammamish River.

The study effort in 2001 represents a continuation of a pilot study conducted in 2000. Results of the 2000 study will be discussed in context with results obtained in 2001;

however, due to the short survey period of 2000, the initial findings were used only to corroborate the general findings of the 2001 study. The 2001 field season incorporated additional survey sites along the Sammamish River to increase sample coverage of created habitats constructed in 2000 and was extended to include what is thought to be the period of juvenile salmonid migration through the Sammamish River (February through July). Additional monitoring sites were added within the transition zone to provide baseline information for the Remeander Project. Specifically, the objectives of the study were to:

1) Determine juvenile salmonid use of created habitats along the Sammamish River;

2) Identify important naturally occurring habitat types for juvenile salmonids rearing in the Transition Zone of the Sammamish River;

3) Measure growth of juvenile salmonids rearing in the Sammamish River;

4) Determine relative abundance of Sammamish River juvenile salmonids; and

5) Determine length of residency of juvenile salmonids in the Sammamish River.

2. ENVIRONMENTAL SETTING

2.1 STUDY AREA

Lake Washington consists of over 22,000 surface acres in the heart of the Puget Sound, in King County, Washington. The Sammamish River basin accounts for approximately 30% of surface water flow into Lake Washington (Pflug 1981; Weitkamp et al. 2000). The Sammamish River begins at the outlet of Lake Sammamish (the sixth largest lake in the State of Washington), approximately one mile southeast of the City of Redmond (Figure 1). The river travels for approximately 8.5 miles north, passing through Woodinville, where it turns west for approximately 4.5 miles and enters Lake Washington near Kenmore. The Sammamish River basin was assigned to Water Resource Inventory Area No. 8 (Lake Washington) by Williams et al. (1975). The entire Sammamish River drainage basin encompasses approximately 170 square miles, including mainstem tributaries Big Bear/Cottage Creek, Little Bear, North, and Swamp creeks that originate in both King and Snohomish counties (Ostergaard et al. 1995; King County Online Data). Big Bear Creek enters the Sammamish River downstream of Marymoor Park, near the intersection of the Sammamish River and Highway 520. Big Bear Creek receives water from Cottage Lake and Evans creeks. Little Bear Creek joins the Sammamish River near Woodinville, while North Creek reaches the Sammamish River in Bothell, and Swamp Creek enters between Bothell and Kenmore (Figure 1). The waters and areas adjacent to the Sammamish River create numerous recreational opportunities and provide for the support of several anadromous fish runs in the Lake Washington watershed. The watershed contains a mix of urban, park, agricultural, and forested areas.

The Sammamish River watershed has experienced considerable development pressures in the last thirty years. The Sammamish River has been straightened to convey a 40-year springtime flood event; the riparian vegetation has been removed or altered over most of its course; large woody debris has been removed from within the channel (Warner et al. 1999). Mean daily summer water temperatures in the Sammamish River consistently exceed 16EC, while maximum water temperatures have been recorded as 23-27EC, which exceed Washington Department of Ecology Class AA surface water quality standards (Martz et al. 1999). The Sammamish River also is on the 1996 Washington State 303(d) list for fecal coliform and low dissolved oxygen levels. In addition to water quality and mainstem habitat issues, fish encounter impaired passage to many tributaries entering the Sammamish River and at a flood control weir, located approximately 0.5 miles downstream of Lake Sammamish. This structure was modified in 1998 by the U.S. Army Corps of Engineers and now is conducive to fish passage at most flows (Warner et al. 1999).

Figure 1. Sammamish River basin, King County, Washington, 1999.

A baseline habitat survey of the Sammamish River, consisting of the following four modules: reference point cross-section survey; habitat unit survey; vegetation unit survey; and large woody debris survey was conducted following Timber-Fish-Wildlife ambient monitoring program (Schuett-Hames et al. 1994) in 1999 (Jeanes and Hilgert 1999). Results of the survey indicate that the Sammamish River is dominated by glide habitat type, which composed more than 98% of all habitat by area (Table 1). The next most common habitat was riffle (1.4%), followed by pool (0.4%). Mean channel width at ordinary high water mark (OHW) for all transects in the Sammamish River is 78 ft, while mean wetted width is 71 ft. Average water depth for all Sammamish River transects is 3.0 ft, while water velocity averaged 0.25 fps at all transects. Aquatic vegetation, most notably Eurasian water milfoil (*Myriophyllum spicatum*) was encountered at four out of 25 transects. Mean transect coverage by aquatic vegetation in the Sammamish River was 9%, while riparian overhang of the river was lacking in all but a few transects. In general, survey data indicate that the Sammamish River is a wide, slow moving stream that lacks habitat diversity throughout most of its entirety (Jeanes and Hilgert 1999).

2.2 BIOLOGICAL RESOURCES

Despite the lack of habitat diversity in the mainstem Sammamish River, both resident and anadromous salmonids inhabit the Sammamish River basin throughout the year, and because of its geographical setting between two large mesotrophic lakes, the Sammamish River also contains a diverse array of non-salmonid species. Mixed (native and non-native origin) stocks of summer/fall chinook occur in the Sammamish River basin. Naturally spawning chinook occur in Issaquah Creek, the largest tributary to Lake Sammamish, and the Bear/Cottage Creek system. The naturally spawning population in Issaquah Creek is located primarily below the hatchery rack and depends on supplementation from the Issaquah Creek Hatchery. This stock is thought to be non-native to the basin, as transfers from the Green River have been released since 1953 (WDFW et al. 1994; Warner et al. 1999). Natural spawning chinook existing in Bear/Cottage Creek and other tributaries to the Sammamish River are thought to be native; however, these fish may be influenced by strays from the Issaquah Creek Hatchery. Genetic Stock Identification results indicate that Bear Cottage Creek chinook are similar to Issaquah Creek chinook. Interannual variation does not rule out the possibility that chinook from these two streams are independent population, however (Mavros et al. 2000). Escapement estimates for Issaquah Creek averaged 1,993 per year from 1986-1991, while Bear/Cottage Creek chinook have been below the escapement goal of 350 the same period of record (WDFW et al. 1994). Recent information indicate that Bear/Cottage Creek chinook exceeded escapement levels during the 1999 spawning season

Table 1. Reference point, reach habitat composition (%), total length of habitat in reach (ft), and mean width of habitat in reach (ft) for mainstem Sammamish River habitat surveys, King County, Washington, 1999.

Reference Point	Glide (%)	Total Length (ft)	Mean Width (ft)	Pool (%)	Total Length (ft)	Mean Width (ft)	Riffle (%)	Total Length (ft)	Mean Width (ft)
L. Samm.									
1	100	1,090	120						
2	71	1,705	100	8	185	78	20	1,060	45
3	91	2,150	43	1	15	50	8	200	48
4	95	700	55	5	35	55			
5	98	1,900	49				2	50	45
6	100	2,100	50						
7	100	2,000	55						
8	98	5,000	59				2	100	52
9	100	950	50						
10	100	2,200	55						
11	100	2,950	55						
12	100	5,500	58						
13	100	1,700	60						
14	100	4,950	67						
15	100	1,500	60						
16	100	2,550	65						
17	94	500	60				6	50	40
18	97	1,675	73				3	100	40
19	100	3,700	64						
20	100	3,500	77						
21	100	2,725	92						
22	100	4,775	90						
23	100	5,950	91						
24	100	1,375	108						
25	100	2,050	143						
L. Wash.	100	1,700	175						
Mean/Total River	***98.2%***	***68,690***	***74***	***0.4%***	***235***	***65***	***1.4%***	***1,560***	***45***

(Mavros et al. 2000). Life histories of Sammamish River chinook are similar to other Puget Sound chinook. Adults arrive at the Chittenden locks in mid-June and enter the river late August and early September. Spawning peaks in the Cedar River in early October and continues through mid-November (Warner et al. 1999). Juvenile chinook from the Cedar River enter Lake Washington from the first day outmigrant trapping occurs, in mid-January and continues through July and August. Juvenile chinook in the Cedar display two noticeable peaks in downstream movement, one occurring late February/early March and the other occurring in early June (D. Seiler; WDFW; pers. comm.). A screw trap was installed in Bear/Cottage Creek to collect downstream migrating juvenile salmonids during the 1999 outmigrant season. Preliminary information indicates that the majority of chinook outmigration occurs in Bear Creek by mid-July (Seiler 2000).

Mixed stocks of coho salmon were consistently planted in the Sammamish River basin beginning in the 1950s and continuing through the early 1970s (WDFW et al. 1994). From 1982 through 1991, hatchery releases of juvenile coho into Issaquah Creek averaged more than three million fish per year. The Lake Washington/Sammamish tributary coho stock was listed as depressed as escapements from 1989 through 1992 were the lowest on record. Adult coho enter Sammamish River in late September through mid-November, and like other Puget Sound coho, spawn from late October through December. Juvenile coho typically spend an entire year in freshwater and move downstream to saltwater as yearlings (Sandercock 1991).

Sockeye salmon were first introduced into the Lake Washington and Sammamish River basin in 1935 with releases of Baker River sockeye into the Cedar River and Issaquah Creek (WDFW et al. 1994). Prior to this, large numbers of native kokanee (non-anadromous form of sockeye salmon) spawned in several Lake Sammamish tributaries during the early 1900s (Ostergaard et al. 1995; R2 2000). These early kokanee stocks were supplemented with kokanee stocks originating from many lakes in Washington, the last of which occurred in 1979. Currently, Issaquah Creek supports the only remaining native kokanee population in the Sammamish River basin. This stock is separated from other stocks in the Sammamish River basin by its unique run timing, generally occurring in August and September. Peak kokanee run timing in the Bear/Cottage Creek occurs later during mid-September and October (Ostergaard et al. 1995). Spawning populations also occur in Swamp and Little Bear creeks (Ostergaard et al. 1995; Ostergaard et al. 1998). A non-native run of kokanee also occurs in Issaquah Creek from October through November, resembling the timing of Lake Whatcom kokanee, a popular choice for many kokanee plants within the Sammamish River basin. Spawning surveys conducted in the Sammamish River basin indicate that the native kokanee population ranged from 0-70 adults per year from 1990 through 1998 (Ostergaard et al. 1995; Ostergaard et al. 1998). Both sockeye and kokanee require a lake environment for at least part of their life cycle. Kokanee mature in freshwater and spawn in tributaries or along the lake shoreline, whereas sockeye move to saltwater after a period of approximately 15 months of residence in freshwater (Burgner 1991).

Winter steelhead, the anadromous form of rainbow trout, reside in Issaquah, Big and Little Bear, and Swamp Creeks (King County SWMD 1993; WDFW et al. 1994). The wild steelhead runs in the Sammamish River are in severe decline, which is often attributed to marine mammalian predation below the Chittenden Locks (WDFW et al. 1994). Total wild escapement has ranged from 474 to 1,816 from 1984 through 1992, exceeding the wild escapement goal only once during that period. Wild juvenile steelhead spend from one to several years in freshwater habitat before moving to saltwater, and typically return to spawn in freshwater within 2-4 years (Peven 1990; Busby et al. 1996). In general juvenile downstream migration for steelhead smolts in Puget Sound occurs from April through June, with peak migration occurring in mid-April (Wydoski and Whitney 1979). Spawning of wild winter steelhead takes place in the spring from March through June, while hatchery fish tend to spawn earlier, in January and February (WDFW et al. 1994).

Coastal cutthroat trout are found throughout the Lake Washington basin in both resident and anadromous life history forms (King County SWMD 1993). Status of cutthroat trout in the Sammamish River basin has not been determined, yet populations appear to have increased in recent years (King County SWMD 1993). Coastal cutthroat trout of the Sammamish River exhibit early life history characteristics similar to coho and steelhead whereby juveniles spend extensive time rearing in freshwater before outmigrating as smolts (Leider 1997). While little information exists on Sammamish River cutthroat, Puget Sound cutthroat emigrate to estuaries at a younger age (age II) and smaller size (6 inches TL) than cutthroat that are exposed to rough coastal waters (age III to V; 8-10 inches TL) (Johnston 1982). Adult cutthroat trout in western Washington tend to follow two run-timings (Johnston 1982). Early returning cutthroat trout typically peak in large streams in September and October. Late-returning cutthroat trout peak in December and January in small streams draining directly to salt water.

A self-sustaining bull trout (*Salvelinus confluentus*) population occurs in the Lake Washington basin in the upper Cedar River, but populations of bull trout have not been confirmed in the Sammamish River (WDFW 1998; Berge and Mavros 2001). A single observation of native char occurred in Carey Creek, a small tributary of Issaquah Creek (Berge and Mavros 2001). Water temperatures in the Sammamish River in excess of 16EC exceed the thermal tolerance exhibited by bull trout, and probably prevent them from residing in the river for most periods of the year (Goetz 1989). Native char in Puget Sound and coastal streams may express both resident and migratory life history forms (USFWS 1998). Resident bull trout complete their life cycles in native tributaries, while some migratory bull trout adopt an anadromous life cycle. Anadromous fish migrate to sea in the spring and return in late summer and early fall (Wydoski and Whitney 1979). Native char can spend two or even three years in freshwater before migrating to sea. Spawning in most native char populations occurs in September and October, though it may occur in August at elevations above 4,000 feet in the Cascades and as late as November in coastal streams (Goetz 1989; Craig 1997; R. Ladley, Puyallup Tribe, pers. comm). Most anadromous populations spawn only every second year while resident char may spawn every year (Armstrong and Morrow 1980; USFWS 1998).

At least 23 non-native predator/competitor species are present in the Lake Washington basin (Weitkamp et al. 2000). Because of its locale, situated between two large lakes, the Sammamish River also contains a variety of native and introduced non-salmonid fishes. Reproducing populations of smallmouth bass (*Micropterus dolomieui*) and largemouth bass (*M. salmoides*), yellow perch (*Perca flavescens*), northern pikeminnow (*Ptychocheilus oregonensis*), largescale sucker (*Catostomus macrocheilus*), threespine stickleback (*Gaterosteus aculeatus*), and sculpin (*Cottus spp*.) have been documented in sections of the Sammamish River, while other species are likely residents during specific periods of the year.

3. METHODS

The study reach encompassed the Sammamish River, beginning near the outlet from Lake Sammamish, and continued downstream to the mouth of the Sammamish River near Kenmore (Figure 2). The selection of candidate sites was based physical habitat data collected by Jeanes and Hilgert (1999) and biological data collected from a pilot study, initiated during the 2000 migration season. The pilot study was initiated to compare juvenile use of mitigation and restoration sites in the Sammamish River (e.g., setback levees and large woody debris) to their use of natural habitats[1]" in the Sammamish River. Monitoring also quantified the time period that juvenile salmonids inhabit the Sammamish River. The pilot study area encompassed 15 sites situated along the entire length of the Sammamish River from the outlet of Lake Sammamish, downstream to its confluence with Lake Washington.

Additional locations were established in 2001 to monitor stream enhancement sites constructed during the previous year by the City of Redmond (i.e., Redmond's Riverwalk HEP 2 Project near the 90th Street Bridge), and in the Transition Zone of the Sammamish River along Marymoor Park. These sites were added to the study during the 2001 study year because they provided a unique opportunity to monitor a recently constructed habitat (City of Redmond's Riverwalk Project) and to provide baseline information for a project that is slated to begin in the near future (King County DNR Remeander Project). A total of 22 sites (15 from pilot study and 7 new sites) were monitored beginning in late February and continuing through July (Table 2; Figure 2). All site locations consisted of nearshore (i.e., bank or lateral) habitat and were 330 feet in length.

3.1 NIGHTTIME ELECTROFISHING SURVEYS

For the purpose of this study, habitat areas in the Sammamish River were separated into the following strata (adapted from Murphy et al. 1989; Hawkins et al. 1993; Coccoli 1996; Hayman et al. 1996; Hilgert and Jeanes 1998; R. Peters, USFWS, pers. comm.):

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[1]The term "natural" refers to conditions of a confined uniform channel and does not confer pre-settlement conditions.

Figure 2. Location of 22 survey sites, Sammamish River, Washington, 2001.

Table 2. Site name, location (approximate river mile), site number, habitat strata, habitat sub-unit, and study objective number associated with the 22 juvenile salmonid mainstem margin survey sites, Sammamish River, Washington, 2001.

Site Name	Approximate River Mile	Site No.	Habitat Strata	Habitat Sub-unit	Study Objective
Rowing Club Nearshore	13.6	22	Natural	Transition Zone	2,3,4,5
Rowing Club Offshore	13.6	21	Natural	Transition Zone	2,3,4,5
Tennis Ball	13.2	20	Natural	Transition Zone	2,3,4,5
Cattail	13.2	19	Natural	Transition Zone	2,3,4,5
Marymoor Park	13.0	18	Constructed	Setback Levee w/o LWD	1,3,4,5
Highway 908 Bridge	11.8	17	Natural	Natural	1,3,4,5
Cold Fusion	11.4	16	Constructed	Setback Levee w/o LWD	1,3,4,5
Senior Center HEP2	11.3	15	Constructed	Setback Levee w/o LWD	1,3,4,5
90th Street Bridge HEP2	11.2	14	Constructed	Setback Levee w/ LWD	1,3,4,5
HEP2 Control	11.2	13	Natural	Natural	1,3,4,5
Powerline Test	10.8	12	Constructed	Setback Levee w/ LWD	1,3,4,5
Powerline Control	10.8	11	Natural	Natural	1,3,4,5
R-Factor Upstream Control	6.8	10	Constructed	Setback Levee w/ LWD	1,3,4,5
R-Factor Upstream Test	6.8	9	Natural	Natural	1,3,4,5
R-Factor Downstream Test	6.8	8	Constructed	LWD	1,3,4,5
R-Factor Downstream Control	6.8	7	Natural	Natural	1,3,4,5
Little Bear Creek Test	5.5	6	Constructed	Setback Levee w/o LWD	1,3,4,5
Little Bear Creek Control	5.5	5	Natural	Natural	1,3,4,5
Bothell Siding Company	4.3	4	Natural	Natural	3,4,5
Cove Site	0.9	3	Natural	Natural	3,4,5
J-Site	0.8	2	Natural	Natural	3,4,5
Kenmore Lumberyard	0.5	1	Natural	Natural	3,4,5

1) **Mainstem channel habitats**: areas with an immediate connection to the mainstem:
   - *Gravel bar pools* formed within high water mark and separated from the main channel only during low flow conditions;
   - *Sloughs* connected to main channel under all flow conditions; and
   - *Margins* along the channel banks and containing areas with relatively low velocity ($\leq$1.0 fps) and overhead cover in the form of woody debris, vegetation, or undercut banks.

2) **Off channel habitats**: disconnected from the mainstem Sammamish River through a vegetated island or abandoned floodplain:
   - *Backbar channels* located along lateral or point bar formations of the mainstem Green River;
   - *Abandoned channels* consisting of former mainstem Green River channels, presently connected at high flow;
   - *Wallbase channels* located along the base of steep valley slopes and receive a considerable proportion of their water supply from side-slope seepage.

Because of the constricted floodplain of the Sammamish River, all monitoring sites in the Sammamish River during this study were within the mainstem margin habitat strata (no off-channel habitat sites were available). In addition to the above strata, study sites were either designated as constructed or natural sites. Constructed sites were paired with a natural control site that was located immediately upstream or downstream from the constructed (test) site to determine juvenile salmonid use of created habitats along the Sammamish River (see Section 1.2; Study Objective No.1). Constructed sites were further divided into habitat sub-units based on the enhancement technique employed at each site. Three different enhancement techniques were monitored within the constructed habitat module: 1) setback levees containing installed large woody debris; 2) setback levees without large woody debris; and 3) large woody debris installed without a setback levee. Setback levee sub-units were generalized as areas of the Sammamish River where the levee was moved back from the river, thus creating a low to moderately sloping water-bank interface. Natural sites were characterized by steep-sloping water-bank interface and presence of the toe of the levee immediately next to the shoreline. All constructed habitat sites were composed of the same general riparian communities, a mix of blackberries (*Rubus spp.*) and reed canary grass (*Phalaris spp.*), except for the recently constructed Riverwalk HEP2 sites that were not vegetated. One natural site served as control for three test sites at the Redmond Riverwalk

HEP2 Project; however all other constructed (test) sites were paired with their own natural (control) site (Table 2).

Four study sites (two near the Rowing Club Boat Launch and two downstream from the weir) were established within Marymoor Park to identify important naturally occurring habitat types for juvenile salmonids within the Transition Zone of the Sammamish River (see Section 1.2; Study Objective No. 2). Two sites located at the Rowing Club Boat Launch were monitored to examine juvenile salmonids use of Eurasian water milfoil relative to bank habitats. Transition sites located downstream from the weir were monitored to determine juvenile salmonid use of willow (*Salix spp.*) riparian canopy in relation to cattail (*Typha spp.*) riparian canopy (Table 2).

In addition to the constructed habitat and Transition Zone study modules, data collected from all 22 sites were used to generalize: growth, relative abundance, species distribution, and length of residency of juvenile salmonids in the Sammamish River (see Section 1.2; Study Objective Nos. 3-5). Some data (e.g., relative abundance) was analyzed at both the site and river reach level. When data were analyzed by reach, the Sammamish River was arbitrarily divided into four reaches: 1) Lake Sammamish downstream to Marymoor Park (RM 13.0); 2) Marymoor Park downstream to Redmond (RM 10.8); 3) Redmond downstream to Woodinville (RM 5.5); and 4) Woodinville downstream to Lake Washington (RM 0.0).

A site reconnaissance in mid-February 2001 finalized site selection and prepared study sites for biological surveys. Final study site selection and preparation included the following:

- Delineating the upper and lower site boundaries;
- Quantifying available habitat area (water depth, velocity, width, and length);
- Installation of staff gages; and
- Placement of Onset Stowaway® digital temperature recorders at select locations.

The same survey technique (backpack electrofishing) was employed at each site. Surveys began on 20 February and continued through 18 July 2001. Each survey period required a minimum of three personnel; personnel were kept as consistent as possible in order to maintain continuity with data collection procedures. Biological surveys were conducted in two-week intervals. Each two-day survey period consisted of one nighttime trip followed within 24 hrs by a second nighttime trip. During each survey period, the initial nighttime survey site was started within ±30 minutes of sunset. Successive site start times depended largely on the amount of time that it required to complete the prior site and travel to the next site. Electrofishing surveys were not conducted within four days of a full moon to avoid potential inconsistencies with lunar effects (Roper and Scarnecchia 1999).

A SmithRoot, Inc. Model 15-C programmable wave output backpack electrofishing unit, using "straight DC" current was used to conduct electrofishing surveys. Electrofishing began at the lower site boundary and continued to the upstream site boundary. A block net, installed at the upstream boundary, was tested during the pilot study. This technique was abandoned in 2001 because there was not a significant difference between catch from sites using an upstream block net and sites without a block net. One transect (i.e., pass) was electrofished at each survey site; guidelines for electrofishing waters containing salmonids listed under the Endangered Species Act (NMFS 1998) were strictly adhered to during this study. This methodology did not provide population estimates but did result in an index of abundance, while minimizing potential injury to the fish.

Fish were captured with a dip net (3-mm nylon mesh) and placed into a darkened recovery unit where they were anesthetized with 75 mg L^{-1} tricaine methanesulfonate (MS 222). Each fish was then identified to species, measured to the nearest mm fork length (FL), and marked with unique fin clips corresponding to each survey month. Stomach contents of randomly selected sculpin, overyearling coho salmon, and overyearling trout were sampled using techniques adapted from Sheng et al. (1990). Stomach contents were sealed in plastic bags containing 90 percent ethanol. Each sample was labeled with date, survey site, species, total length, and contents (fish tissue, macroinvertebrates, or debris). Captured fish, allowed to recover in fresh water for a minimum of 30 minutes, and then released within the survey site that they were captured. Survey time of electrofishing transects (sec) were recorded along with fish data, staff gage measurements (mm), and water temperatures (°C) on field data sheets.

3.2 HABITAT SURVEYS

Habitat measurements were conducted at each site beginning on 20 February 2001. Juvenile salmonid habitat characterization methods were based on the hierarchical classification system described by Hawkins et al. (1993). Level one habitat identified the channel type as main channel, braided channel, side channel, slough, or tributary mouth. Habitat levels 2-4 classified the primary geomorphic units (i.e., pool, riffle) of the channel, while level 5 characterized the secondary units ($\geq$20%) located within the primary units (Table 3). Level 2 classification consisted of either fast (>2.0 fps) or slow (<2.0 fps) water. Within each Level 5 habitat type (i.e., the fish survey site) we measured the available habitat length (ft), width (ft), mean velocity (fps), maximum and mean water depth (ft), overhead cover (%), overhanging vegetation (%), and undercut bank (%). Habitat Levels 1-4 were characterized once (on 20 February), while parameters measured within Level 5 habitat types were measured on each survey date. Water velocities (to the nearest 0.1 fps) were measured using a Swoffer Model 2100 velocity meter and a 4-ft top-setting rod. Water depths (to the nearest 0.1 ft) were measured using a top-set rod. Bank angle was characterized on a sliding scale from 1 (shallow; ≤ 10º) to 5 (steep; ≥ 90º). Wetted length (to nearest 1 ft) was measured with a Bushnell® Compact 800 rangefinder. The rangefinder was calibrated on each survey using a 300 ft tape. Overhead cover, overhanging vegetation, and undercut banks were visually estimated on each survey occasion. The riparian vegetation was classified as coniferous, deciduous, grass, open, or shrub. The amount of wetted overhanging vegetation was also visually estimated. Large woody debris was characterized at each site on successive survey dates using a methodology adapted from Schuett-Hames et al. (1999). For data consistency, the same survey personnel recorded all visual habitat data metrics.

3.3 DATA ANALYSIS

Intra-site catch per unit effort (CPUE) data were calculated for each species (coho, chinook, and sockeye salmon, and rainbow and cutthroat trout) and life stage (fry and overyearling). Life stages were differentiated by length frequency analysis. Inter-site CPUE data were used to classify periods of residence and test for differences in habitat use of juvenile salmonid species residing in the Sammamish River. Length data was analyzed with recapture information to assign relative growth rates of each species and life stage. Relative abundance of juvenile salmonids were compared to available habitat, water temperature, and stream discharge data to determine the effects of flow regime on juvenile salmonids in the Sammamish River. Provisional stream data (river stage and discharge) was obtained from the U.S. Geological Survey and compared to available habitat information and water temperature data to analyze the effect of different flow regimes on mainstem margin habitat in the Sammamish River. Water temperature data were downloaded from Onset Stowaway® digital water temperature recorders and converted to daily mean, minimum, and maximum water temperatures (°C) using an in-house computer program. Stomach samples were analyzed for the presence of small fish, macroinvertebrates, or debris to determine if a change in diet composition occurs over the duration of the study. All data were entered electronically using MS Excel and cross-referenced with original field data forms for QA/QC purposes. Data analyses were conducted using MS Excel, while all statistical analyses were conducted using Jandel SigmaStat.

Table 3. Description of five-level hierarchical habitat classification system used to characterize 22 juvenile salmonid mainstem margin survey locations, Sammamish River, Washington, 2001. Habitat level 1 delineates main channel habitats from off channel habitats (adapted from R. Peters, USFWS, unpublished data).

Habitat Level 2	Habitat Level 3	Habitat Level 4	Habitat Level 5 (description)
Fast Water			Riffle or rapid/steep water surface gradient
	Turbulent		Non-laminar flow w/ surface turbulence.
		Falls	Steep, vertical drop in water surface elevation
		Cascade	Series of small falls and shallow pools.
		Rapid	Deeper stream section, standing waves present.
		Riffle	Shallow, lower gradient, often w/ exposed substrate
		Chute	Narrow, confined channel w/bedrock substrate
	Non-Turbulent		Low channel roughness, moderate gradient and lack of surface turbulence
		Sheet	Shallow water flowing over bedrock
Slow Water			Slowly moving w/ decreased water surface gradient
		Glide	Shallow water flowing smoothly over other substrate types
	Scour Pool		Formed by scour action of current
		Eddy	Formed by circular current pattern often created by bank obstruction, usually occur along the bank
		Trench	Formed primarily by scouring of bedrock, usually located in the main channel
		Mid-Channel	Formed in the main channel by channel constriction usually at the upstream end of pool
		Convergence	Formed in the main channel by converging stream channels
		Lateral	Formed in the main channel where flow is deflected by a partial channel obstruction
		Plunge	Formed in the main channel by water dropping vertically over a channel obstruction
		Deposition	Depositional area within a scour pool usually located along the point bar of a lateral scour pool.
	Dammed Pool		Water impounded by channel blockage
		Debris	Formed by log and debris jams
		Beaver	Formed by beaver activity
		Landslide	Formed by earth of large boulders
		Backwater	Formed by obstruction along stream margin
		Abandoned Channel	Formed along main channel, often associated with gravel deposition zones

4. RESULTS

4.1 NIGHTTIME ELECTROFISHING SURVEYS

4.1.1 Juvenile Salmonid Data

Juvenile salmonid use was monitored in 22 sites during the 2001 study period (Table 2; Figure 2). The first survey period was conducted on 20 February, while the final survey was completed on 18 July. In general, the lower river sites (those downstream from RM 6.8) were accessed via a small raft and surveyed on the first night; upstream sites were surveyed on the second night and accessed by foot.

A total of 1,627 salmonids were captured during 2001 nighttime electrofishing surveys (Appendix A; Tables A-1 through A-22). The majority of the juvenile salmonids were coho (N=578; 36%), followed by sockeye (N=551; 34%), and chinook salmon (N=311; 19%). The remaining juvenile salmonids were composed of cutthroat (N=163; 10%), and rainbow trout (N=13; <1%), and mountain whitefish (N=11; <1%).

Most (N=283; 91%) chinook captured were considered young-of-year (hereafter referred to as fry) (#110 mm FL) based upon their length frequency distribution and date of capture (Figures 3 and 4). All (N=551) sockeye captured were fry (Figure 5), while the majority of coho (N=545; 94%) were fry as opposed to overyearling (N=33; 6%) (Figures 6 and 7). Likewise rainbow trout fry comprised the majority (N=9; 70%) of all rainbow captured during the 2000 field season (Figures 8 and 9). Only nine cutthroat trout fry (4%) were captured in 2000, the vast majority (N=157; 96%) composed by overyearling cutthroat trout (Figures10 and 11). Catch per unit effort indices for juvenile salmonids captured during nighttime electrofishing for individual sites are presented in Appendix A (Tables A-1 through A-22; Figures A-1 through Figures A-22).

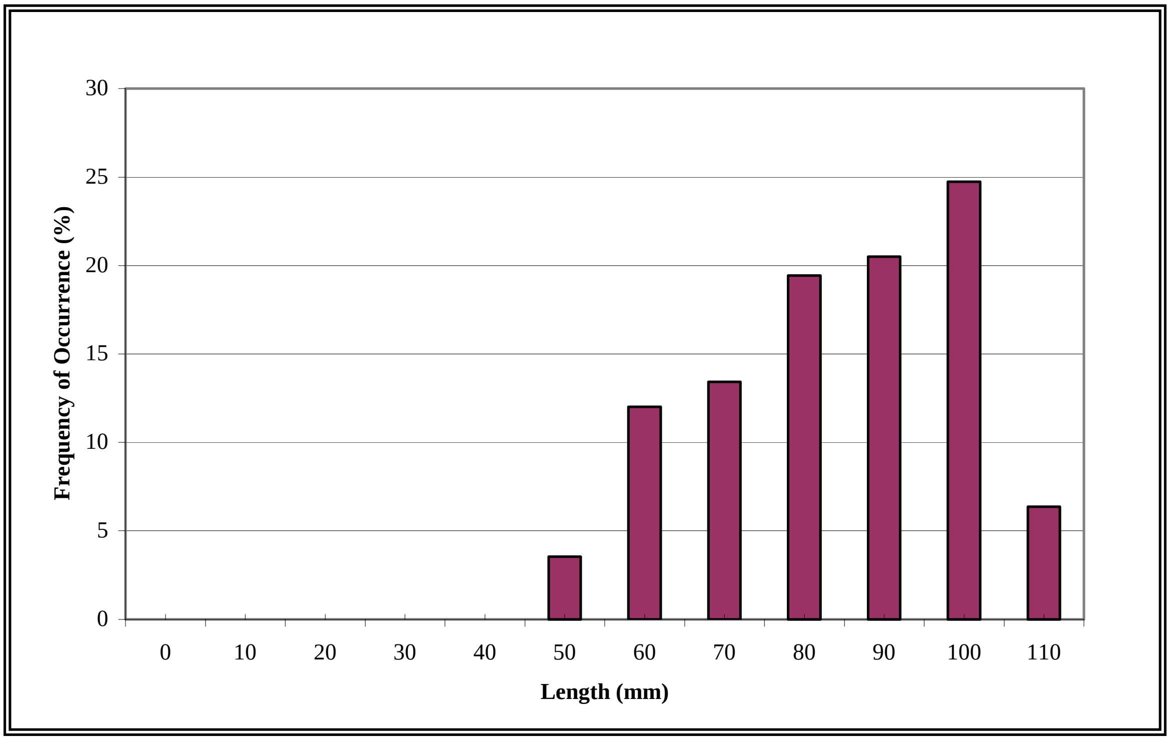

Figure 3. Length frequency of chinook fry captured in the Sammamish River, Washington, 2001 (N=283).

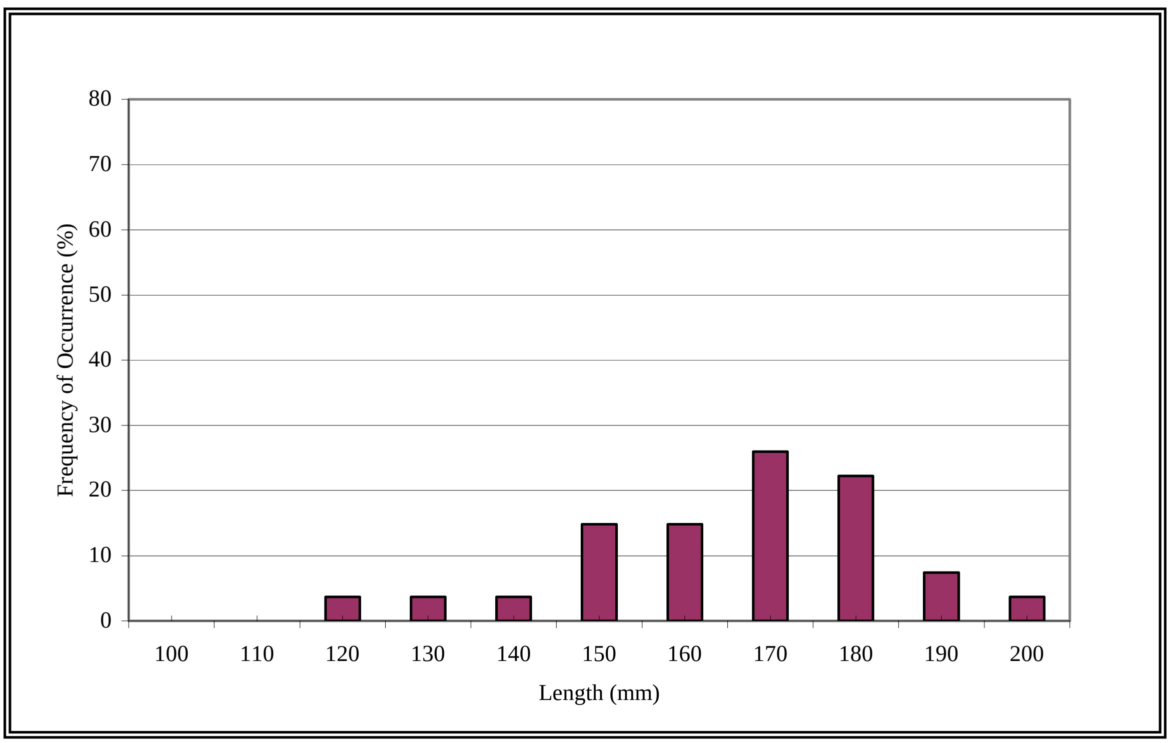

Figure 4. Length frequency of overyearling chinook captured in the Sammamish River, Washington, 2001 (N=27).

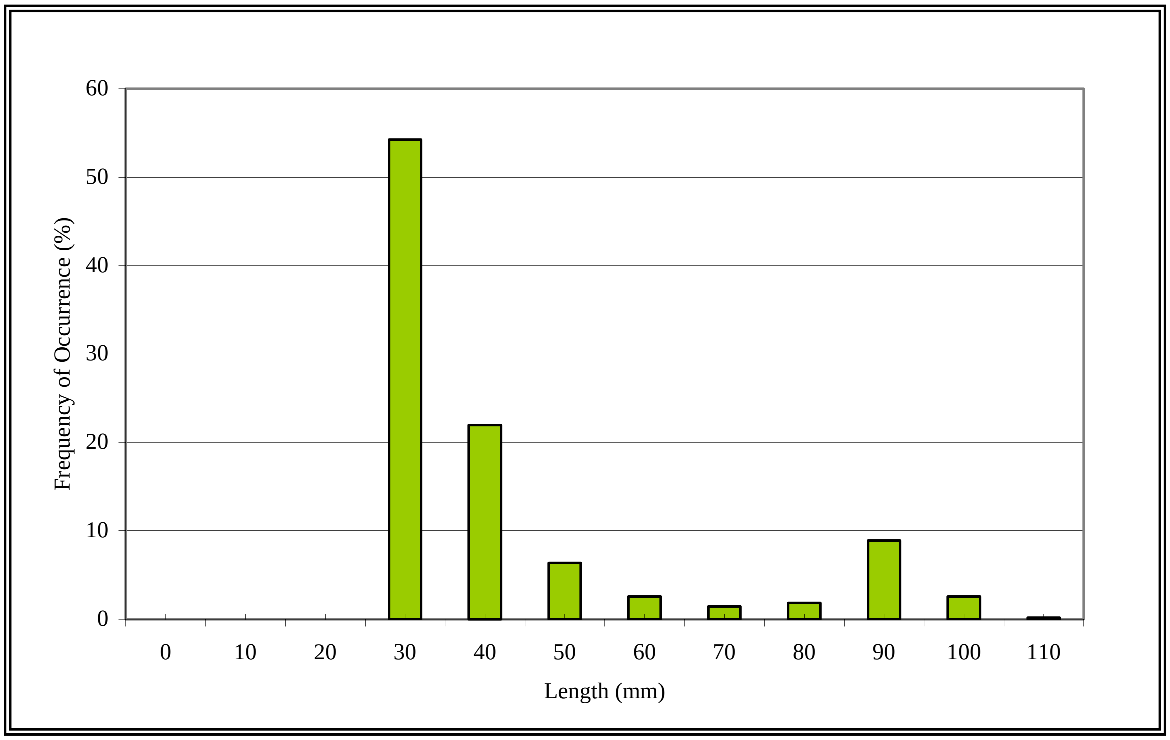

Figure 5. Length frequency of sockeye fry captured in the Sammamish River, Washington, 2001 (N=551).

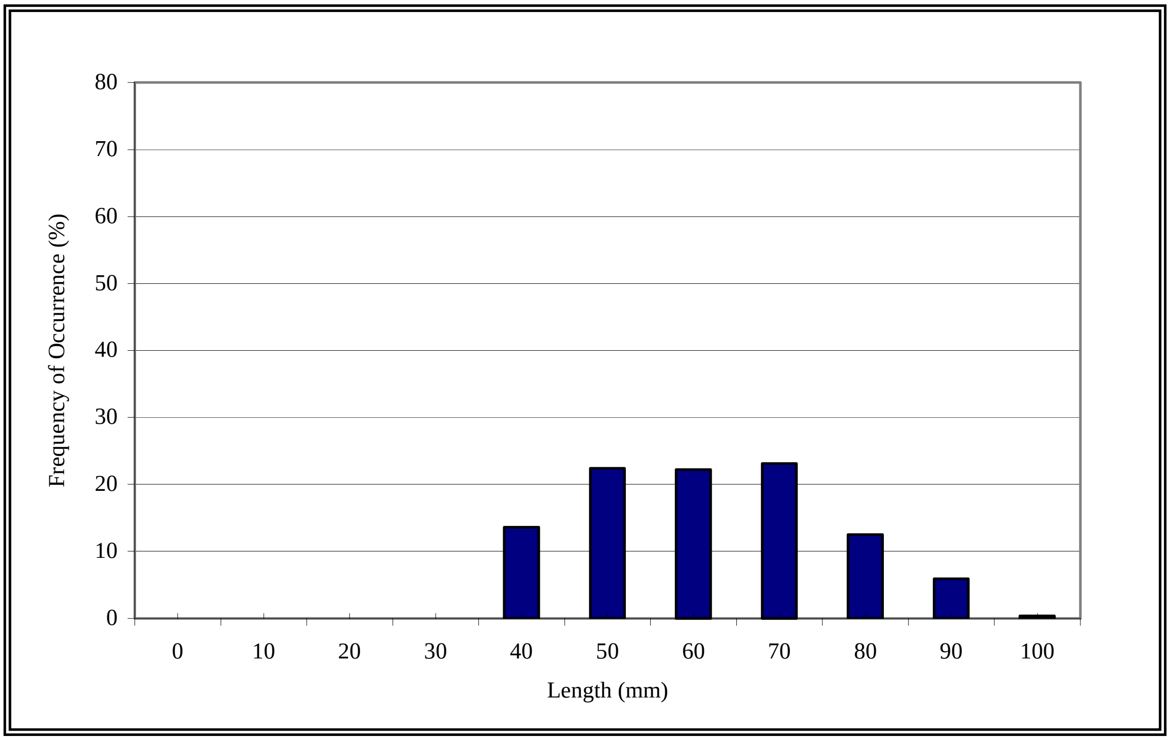

Figure 6. Length frequency of coho fry captured in the Sammamish River, Washington, 2001 (N=545).

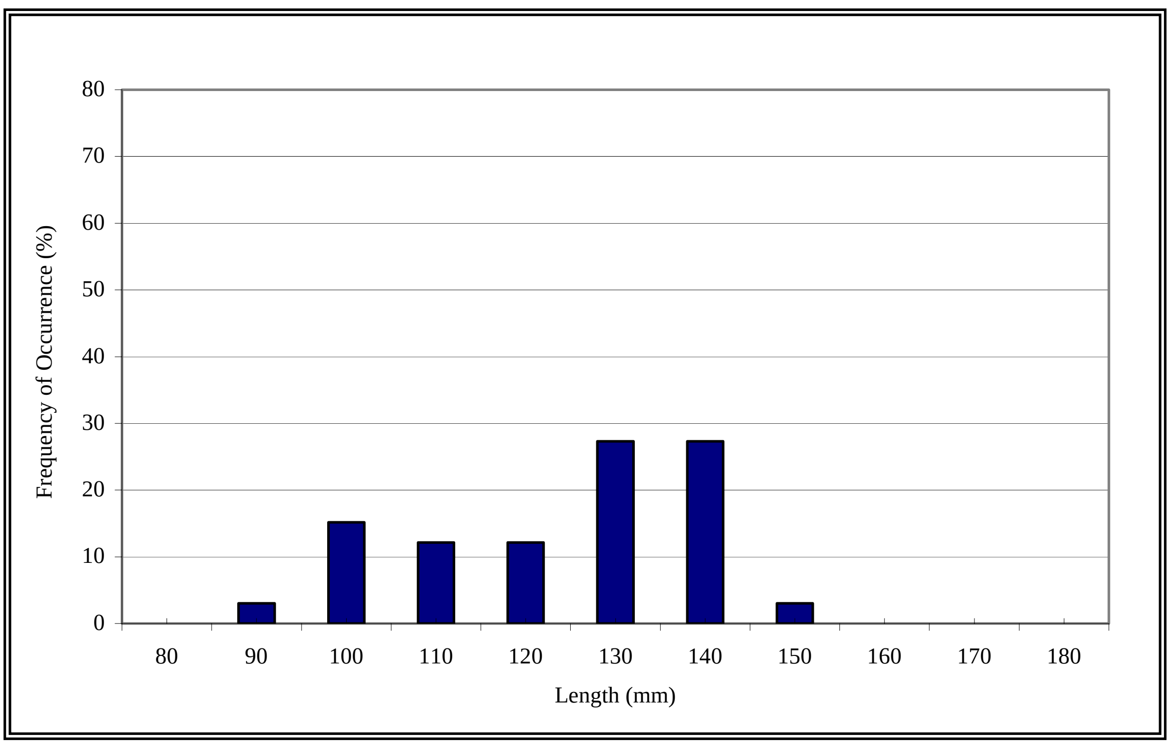

Figure 7. Length frequency of overyearling coho captured in the Sammamish River, Washington, 2001 (N=33).

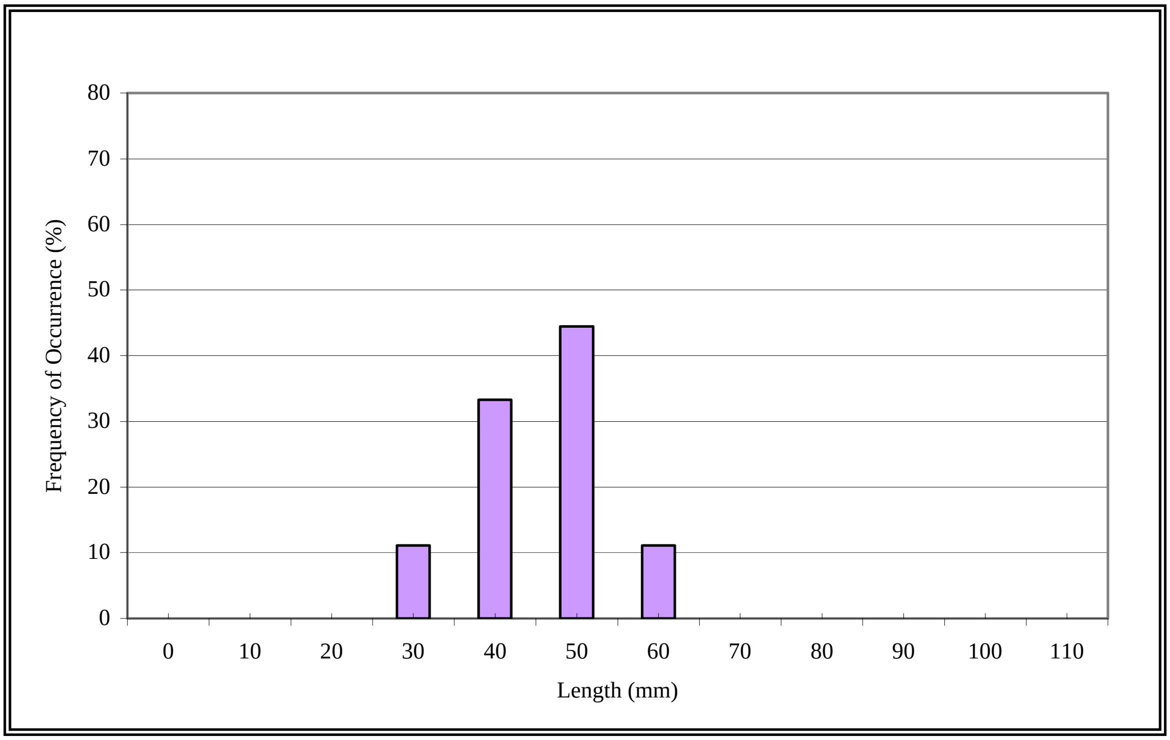

Figure 8. Length frequency of rainbow trout fry captured in the Sammamish River, Washington, 2001 (N=9).

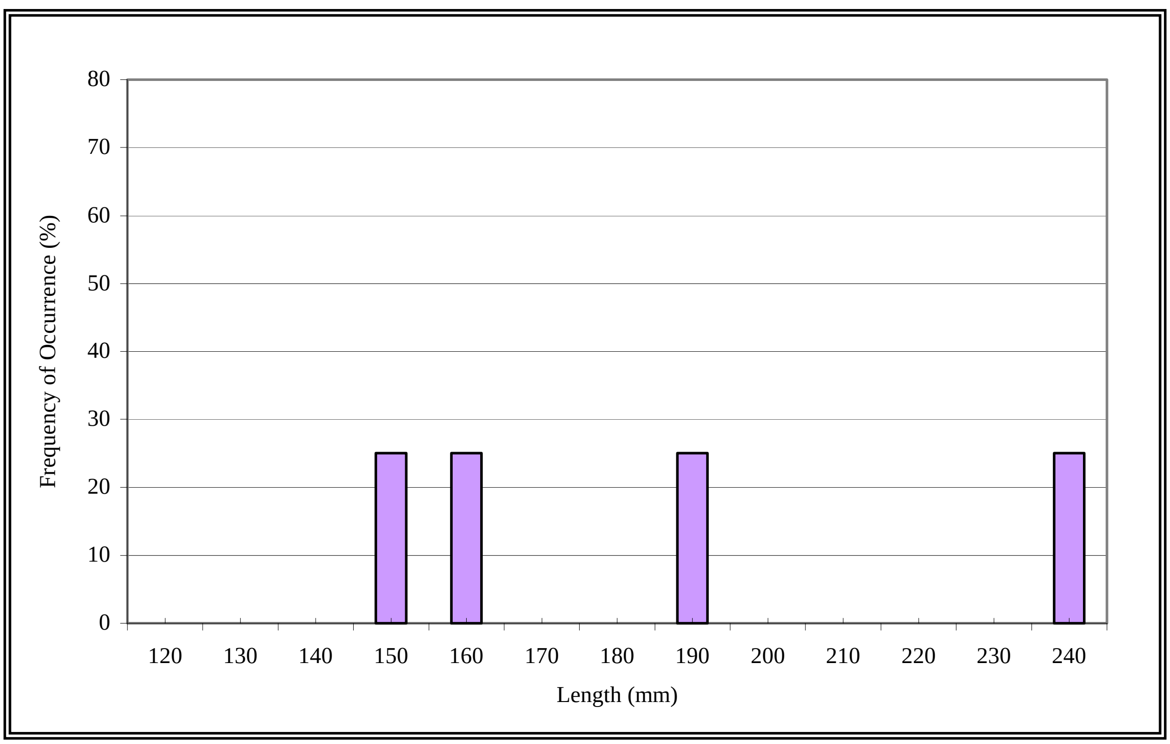

Figure 9. Length frequency of overyearling rainbow trout captured in the Sammamish River, Washington, 2001 (N=4).

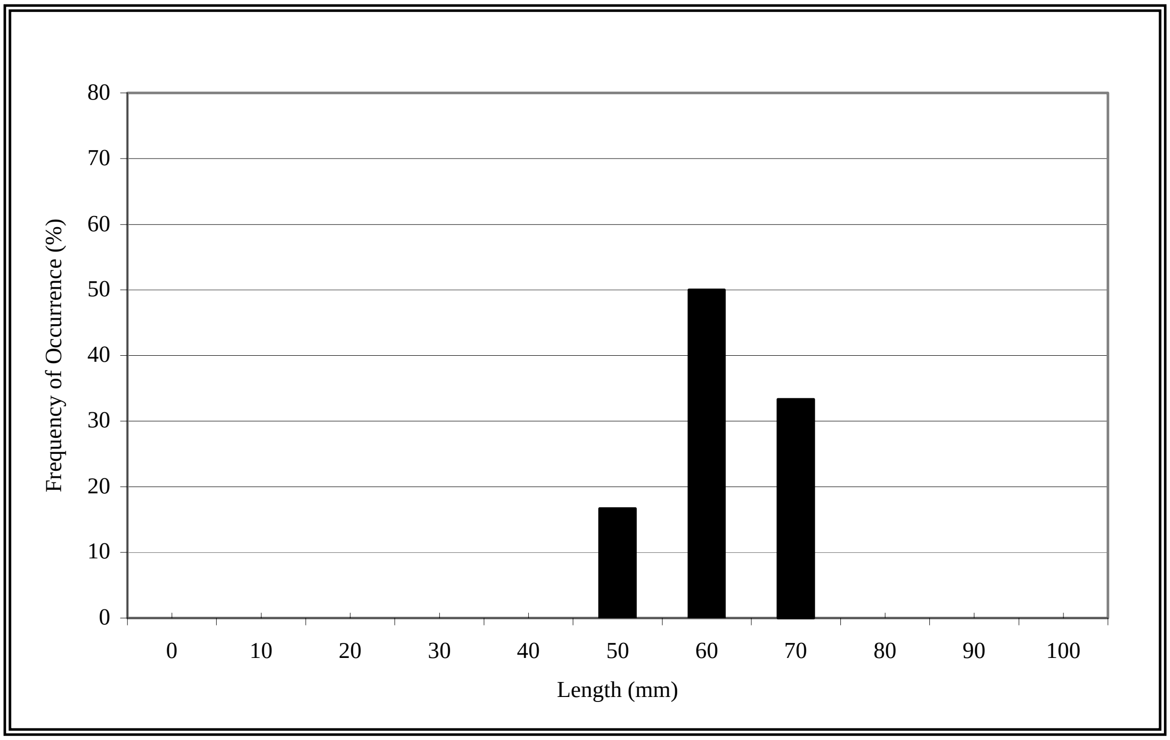

Figure 10. Length frequency of cutthroat trout fry captured in the Sammamish River, Washington, 2001 (N=6).

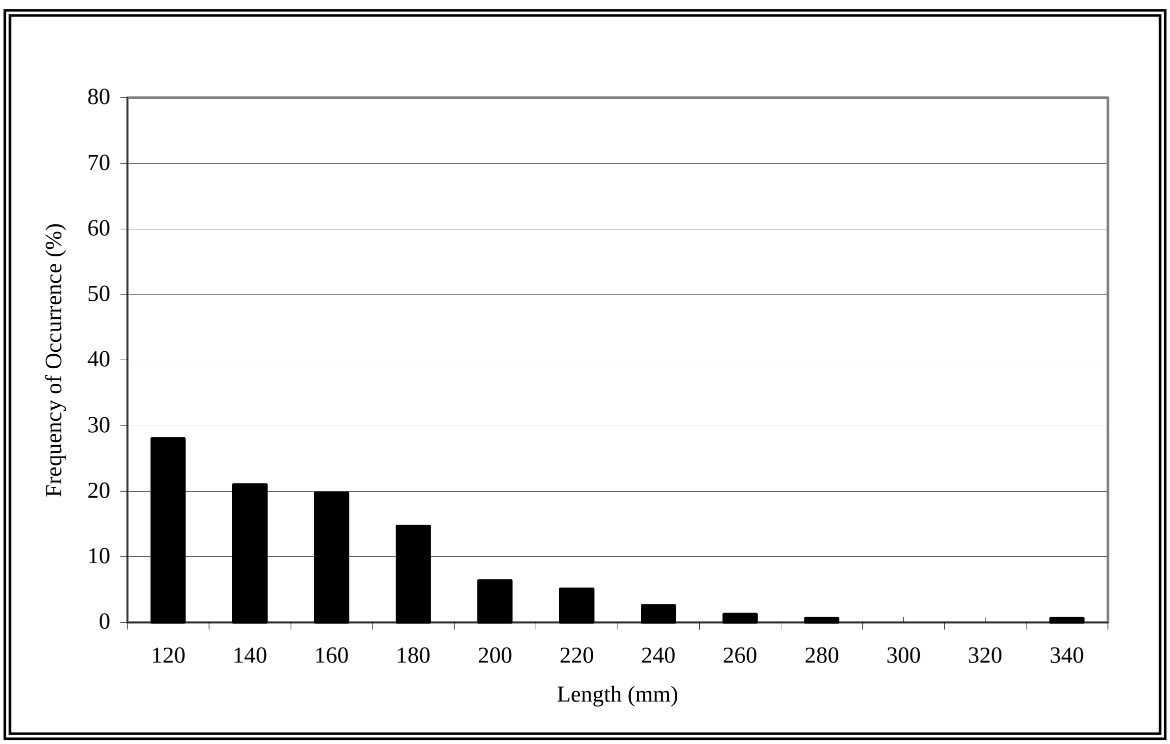

Figure 11. Length frequency of overyearling cutthroat trout captured in the Sammamish River, Washington, 2001 (N=157).

Total Catch Data

Catch (all survey sites combined) of all juvenile salmonids (i.e., chinook, coho, and sockeye salmon, and rainbow and cutthroat trout) peaked (mean CPUE = 0.0274; std. dev. = 0.009) in the Sammamish River during the week of 20 May (Table 4; Figure 12), which also coincided with individual peak of chinook salmon (CPUE = 0.0151). Catch rates of sockeye salmon fry peaked during the survey conducted on 19 March (CPUE = 0.0241). Mean coho salmon capture indices increased steadily from the initial survey date (20 February CPUE = 0.000) through early May (CPUE = 0.0127), decreasing from there until the last survey conducted on 18 July (Figure 12). The catch rates of rainbow and cutthroat trout in the Sammamish River were buoyed by the large percentage of overyearlings and remained fairly constant throughout the survey period (Figure 12). Most of the juvenile salmonid catch (all survey sites and species combined) occurred in the Sammamish River by late May (Figures 13 and 14). Both catch rates (CPUE) and frequency of occurrence remained fairly constant throughout this portion of the migration window, decreasing after early June survey date. The majority (>80%) of sockeye salmon were captured by the end of April (Figures 15 and 16). Chinook salmon catches were relatively low until early May, increased dramatically by late May, and then decreased by the end of June (Figures 15 and 16). Meanwhile, Coho catch increased several weeks before chinook (23 April) and remained fairly constant throughout the remainder of the surveys (Figures 15 and 16).

Table 4. Survey date, number captured, percent of total, cumulative percent, total effort (shock time), and catch per unit effort (CPUE) for 22 juvenile salmonid nighttime survey sites in the Sammamish River, Washington, 2001.

Survey Date	No. Captured	Percent of Total	Cumulative Percent	Total Effort (sec)	CPUE
20 February	8	0.5	0.5	10,057	0.00080
7 March	80	4.9	5.4	10,739	0.00745
19 March	267	16.4	21.8	9,839	0.02714
11 April	197	12.1	33.9	11,029	0.01786
23 April	185	11.4	45.3	10,379	0.01782
8 May	250	15.4	60.7	10,658	0.02346
20 May	271	16.7	77.3	9,886	0.02741
6 June	165	10.1	87.5	10,765	0.01533
19 June	104	6.4	93.9	10,045	0.01035
18 July	100	6.1	100.0	8,313	0.01203
Grand Total	1,627			101,710	0.01599

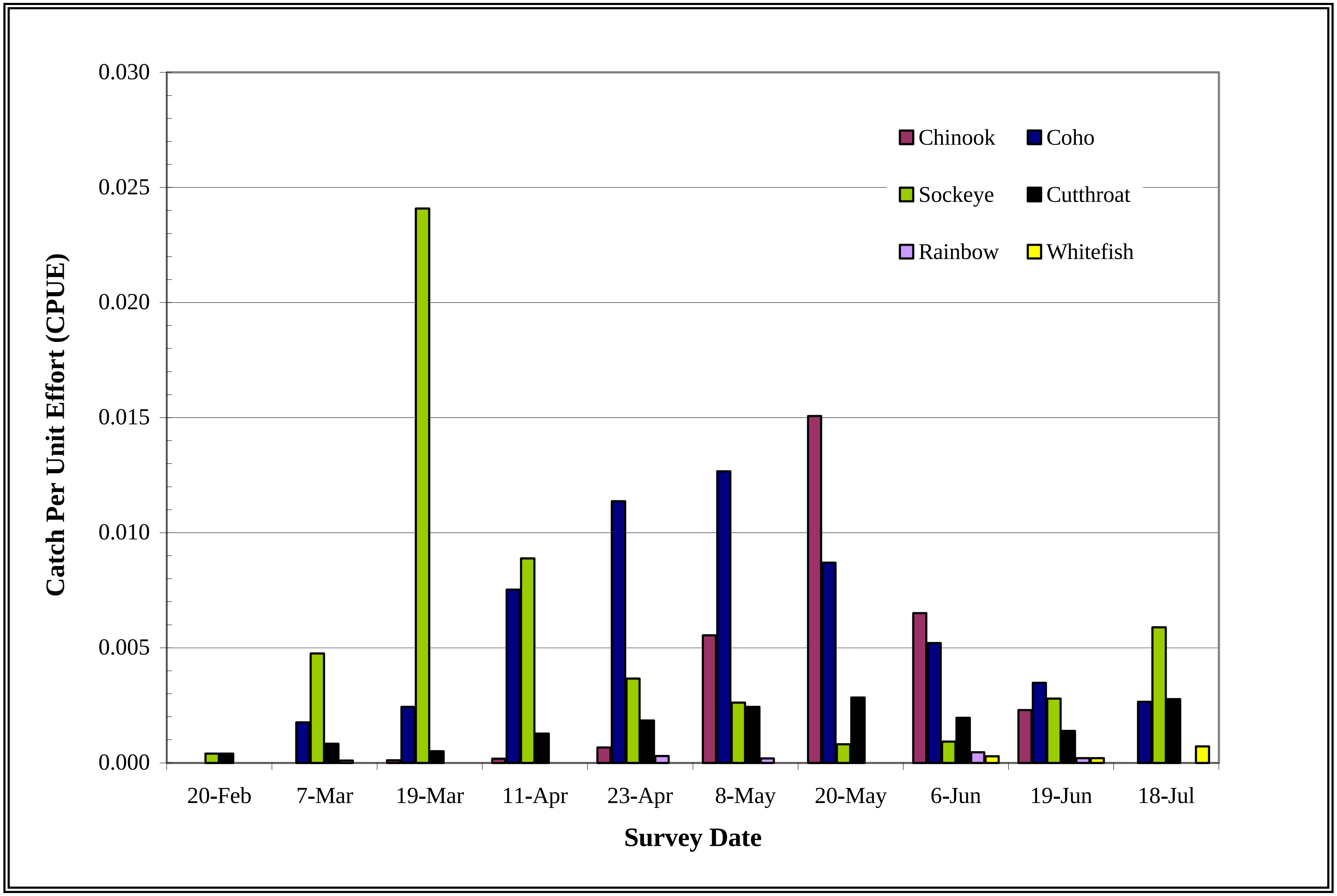

Figure 12. Catch per unit effort indices by species for survey sites located in the Sammamish River, Washington, 2001.

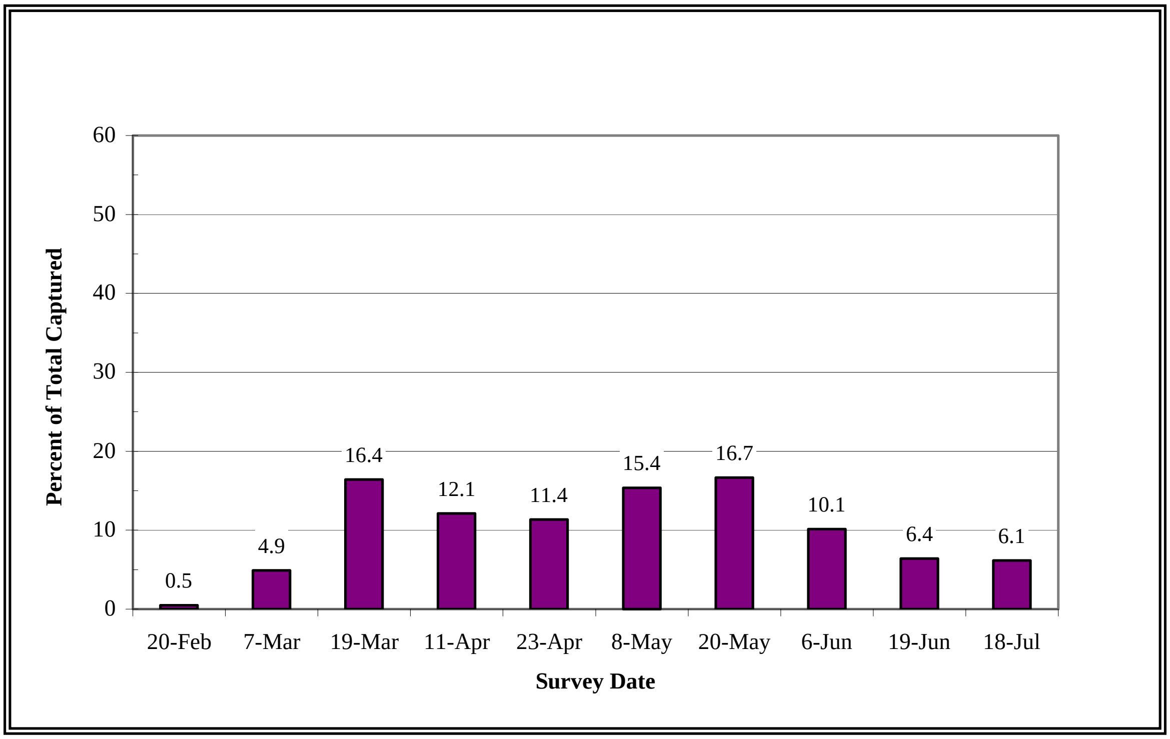

Figure 13. Percent of all juvenile salmonid captures by survey date, Sammamish River, Washington 2001.

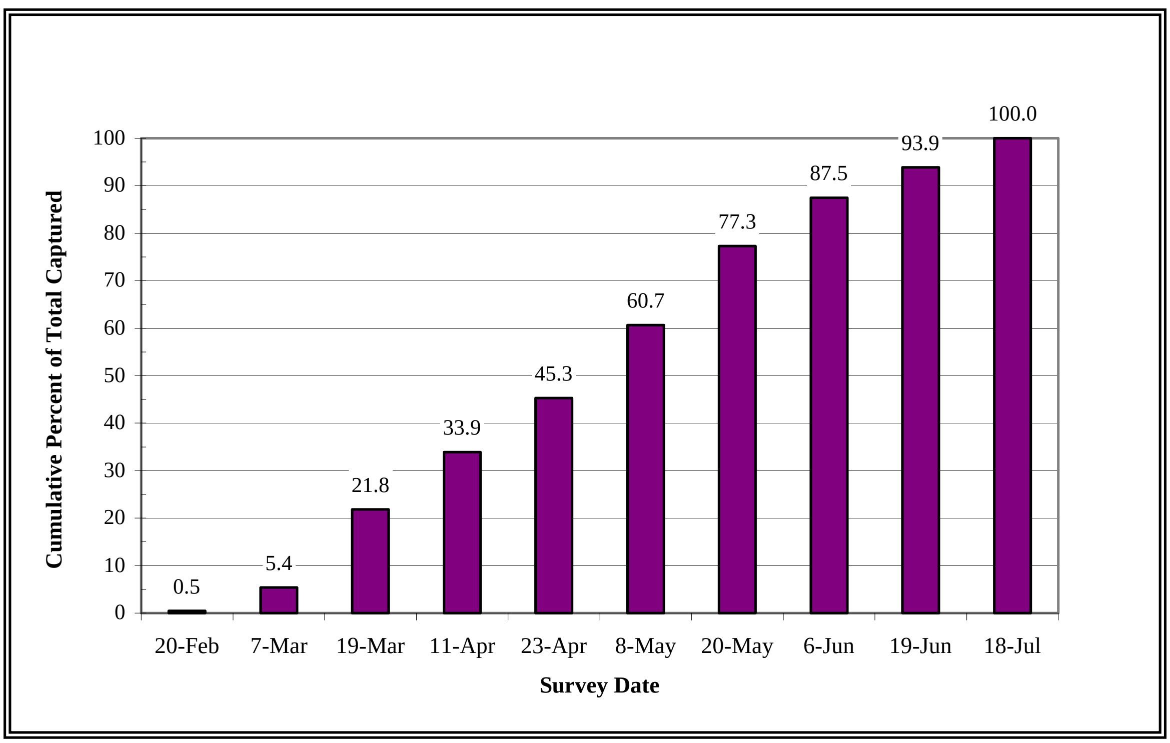

Figure 14. Cumulative percent of all juvenile salmonid captures by survey date, Sammamish River, Washington 2001.

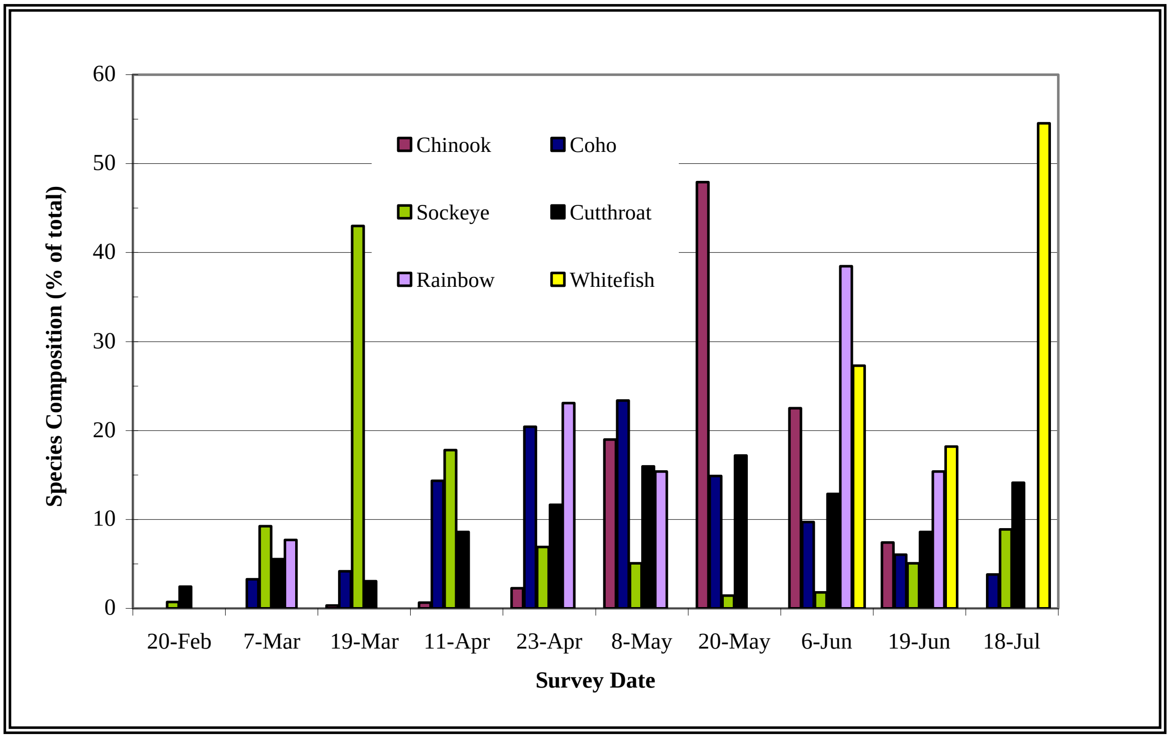

Figure 15. Species composition (percent of species total) for all salmon and trout species captured in the Sammamish River, Washington 2001.

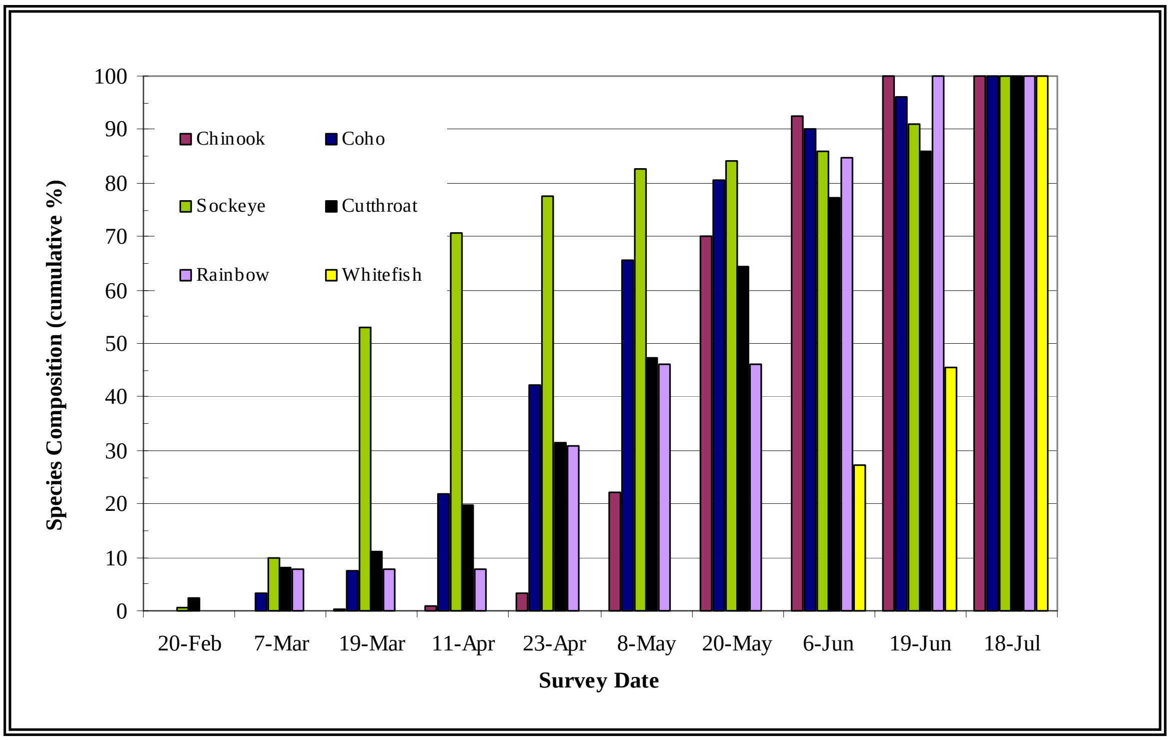

Figure 16. Species composition (cumulative percent of species total) for all salmon and trout species captured in the Sammamish River, Washington 2001.

From the onset of the surveys, the composition of the catch (total catch for each survey date) in the Sammamish River was dominated by sockeye salmon (Figure 17). This pattern continued until late April, when coho fry composed the majority of the catch (>60%). By 20 May, chinook were contributing to more than 40% of the total catch on each survey event (Figure 17). By late June and into July, coho, chinook, and sockeye salmon, and cutthroat trout were all fairly equally distributed in the catch. More than 90% of all juvenile salmonids captured during this study had occurred by those survey dates (19 June and 18 July), however (Figure 14).

Overall, very few juvenile salmonids were recaptured during the study period (Table 5). More coho fry (13.5%), overyearling cutthroat (9.5%) and overyearling coho (3%) were recaptured than any other species and/or lifestage. Only a small percentage of chinook (<1%) and sockeye (<1%) were recaptured during the study period. Coho were the species with the highest overall recapture rate (13%) throughout the study period, while May and June were the months of with the highest recapture rates.

The length of sockeye fry remained fairly constant during February (mean = 29.8 mm; std. dev. = 0.9 mm), and March (mean = 28.3 mm; std. dev 2.2 mm) (Figure 18). Mean length increased dramatically during April (mean = 35.8 mm; std. dev. = 5.1 mm), May (mean = 45.7 mm; std. dev. = 8.9 mm), June (mean = 69.5 mm; std. dev. = 8.9 mm), and July (mean = 87.4 mm; std. dev. = 5.2 mm), however. The lengths of coho fry increased from March (mean = 35.0 mm; std. dev. = 2.0 mm) through April (mean = 46.5 mm; std. dev. = 6.4 mm), May (mean = 61.7 mm; std. dev. = 8.6 mm), June (mean = 71.6 mm; std. dev. = 9.1 mm), and July (mean = 81.0 mm; std. dev. = 6.4 mm). Chinook fry were relatively large when they first appeared in the Sammamish River in April (mean = 58.7 mm; std. dev. 5.0 mm) and increased in size rapidly in May (mean = 73.3 mm; std. dev. = 13.2 mm) and June (mean = 88.2 mm; std. dev. 12.5 mm) (Figure 18). Rainbow and cutthroat trout fry lengths remained fairly constant from April through June, both noticeably smaller than either coho or chinook. Overyearling chinook were considerably larger than their coho counterparts,; the size differential was maintained throughout the study period (chinook mean = 162.9; coho = 119.3) (Figure 19). Overyearling cutthroat trout lengths remained somewhat constant, beginning in February (mean = 158.3 mm; std. dev. = 61.8 mm) and continuing through July (mean = 164.6; std. dev. = 34.3) (Figure 19).

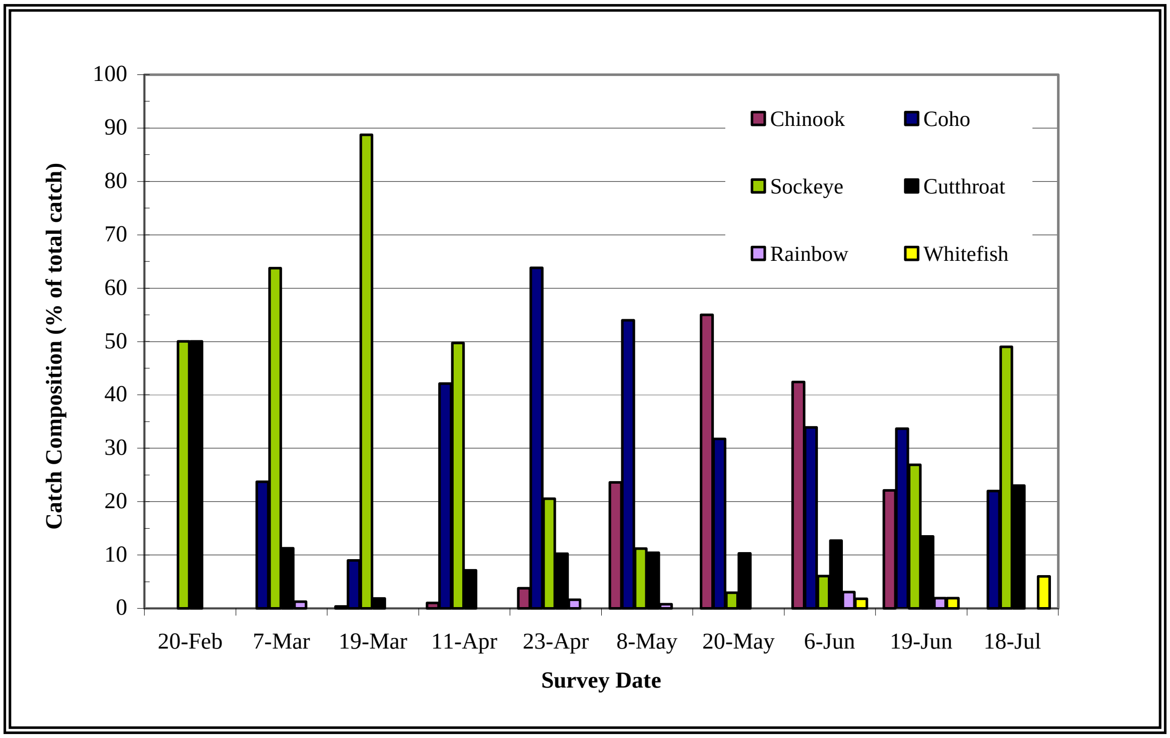

Figure 17. Catch composition (% of catch on survey date) for all salmon and trout species captured in the Sammamish River, Washington 2001.

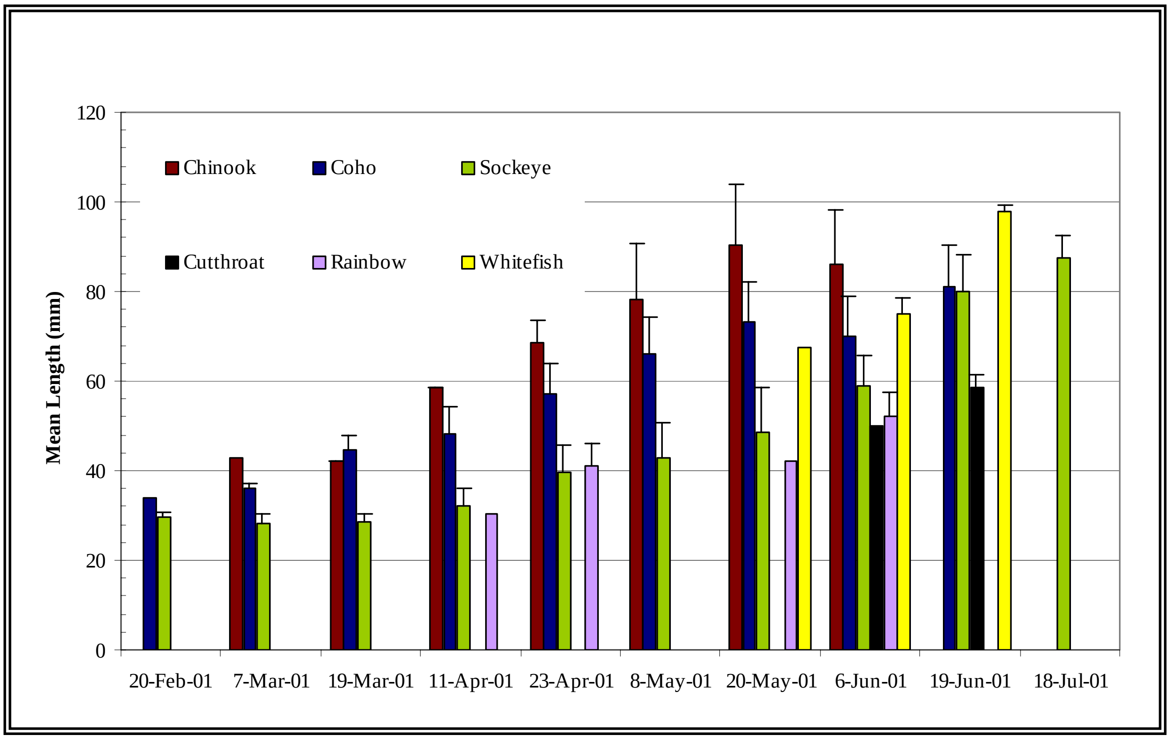

Figure 18. Mean fork length (mm) of all salmon and trout fry captured in the Sammamish River, Washington 2001.

Table 5. Percent of juvenile salmon and trout recaptures (total number of fish for individual cohorts in parenthesis) by life stage occurring in the Sammamish River, 2001.

Initial Capture	% of Total Chinook (N=311)	% of Total Coho (N=578)	% of Total Sockeye (N=551)	% of Total Rainbow (N=13)	% of Total Cutthroat (N=163)
Feb	0%	0	0%	0%	0%
Mar	0%	0	0%	0%	0%
Apr	0%	2.9%	0%	0%	1.2%
May	0.3%	5.5%	0.2%	0%	1.8%
Jun	0.3%	3.5%	0%	0%	3.7%
Jul	0%	1.0%	0%	0%	2.5%
Total	***0.6%***	***13.0%***	***0.2%***	***0%***	***9.2%***
Initial Capture	**% of Fry Chinook (N=283)**	**% of Fry Coho (N=548)**	**% of Fry Sockeye (N=551)**	**% of Fry Rainbow (N=9)**	**% of Fry Cutthroat (N=6)**
Feb	0%	0%	0%	0%	0%
Mar	0%	0%	0%	0%	0%
Apr	0%	2.9%	0%	0%	0%
May	0.4%	6.6%	0.2%	0%	0%
Jun	0.4%	3.6%	0%	0%	0%
Jul	0%	1.1%	0%	0%	0%
Total	***0.7%***	***13.5%***	***0.2%***	***0%***	***0%***
Initial Capture	**% of Age-1+ Chinook (N=28)**	**% of Age-1+ Coho (N=33)**	**% of Age-1+ Sockeye (N=0)**	**% of Age-1+ Rainbow (N=4)**	**% of Age-1+ Cutthroat (N=157)**
Feb	0%	0%	-	0%	0%
Mar	0%	0%	-	0%	0%
Apr	0%	3.0%	-	0%	1.3%
May	0%	0%	-	0%	1.9%
Jun	0%	0%	-	0%	3.8%
Jul	0%	0%	-	0%	2.5%
Total	***0%***	***3.0%***	***-***	***0%***	***9.5%***

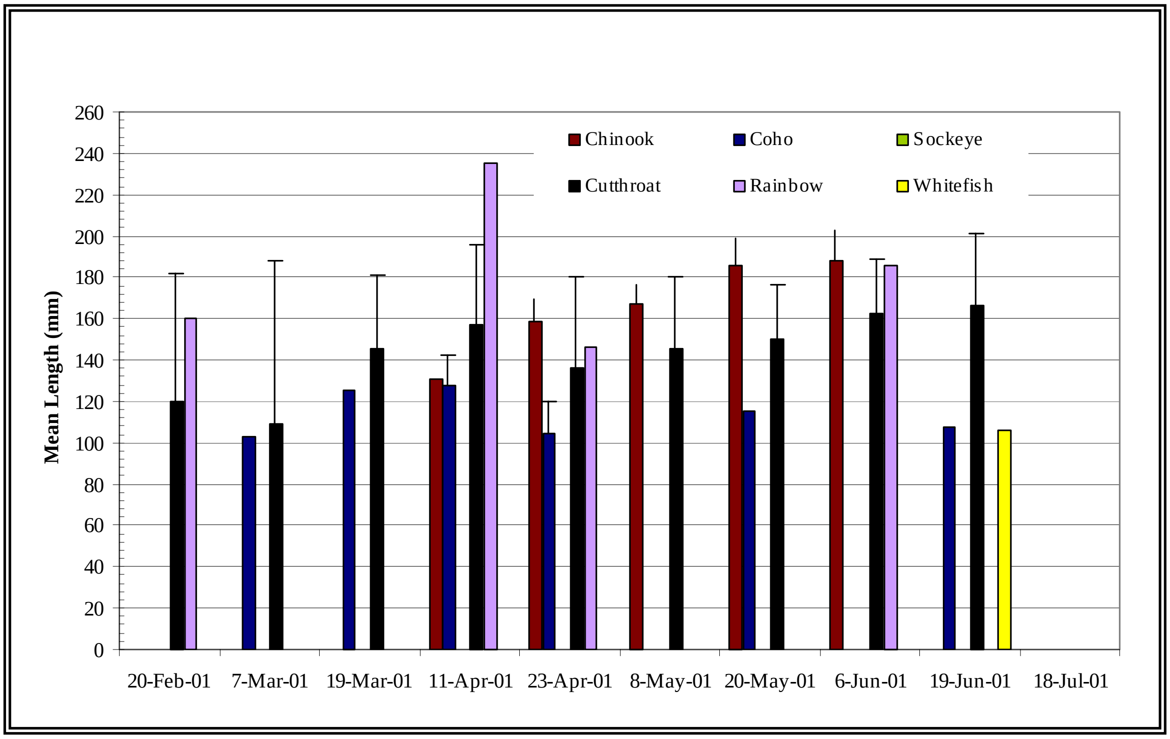

Figure 19. Mean fork length (mm) of all overyearling salmon and trout captured in the Sammamish River, Washington 2001.

Overall, insects comprised more than 50 percent of the stomach contents from February through July (Table 6). Notably, fish flesh was present in 15 percent (90% of which was sockeye) of the stomachs analyzed during March, but was never more than 3 percent of the contents during other months. Cutthroat trout (67%) and prickly sculpin (16%) were the species that had the highest percentage of fish flesh in their stomachs during those months (Table 6). Approximately 11 percent of the stomachs were empty in April. No overyearling coho were captured after the 9 May survey. Approximately 38 percent of all stomachs were empty, 8% contained debris, and 4% contained fish flesh.

Table 6. Frequency of occurrence (%) of age-1+ cutthroat trout and coho salmon, and prickly sculpin salmon gut contents (number of stomachs analyzed in parenthesis) in the Sammamish River, 2001.

Gut Category	Frequency of Occurrence February	Frequency of Occurrence March	Frequency of Occurrence April	Frequency of Occurrence May	Frequency o Occurrence June	Frequency of Occurrence July
Overyearling Cutthroat Trout (101)						
No. Stomachs	(2)	(3)	(10)	(43)	(30)	(13)
Insecta	50%	33%	70%	86%	94%	0%
Fish Flesh	50%	67%	0%	2%	0%	8%
Debris	0%	0%	30%	5%	3%	92%
Empty	0%	0%	0%	7%	3%	0%
Overyearling Coho Salmon (18)						
No. Stomachs	(0)	(0)	(6)	(6)	(5)	(1)
Insecta	0%	0%	100%	100%	60%	0%
Fish Flesh	0%	0%	0%	0%	0%	0%
Debris	0%	0%	0%	0%	20%	100%
Empty	0%	0%	0%	0%	20%	0%
Prickly Sculpin (845)						
No. Stomachs	(143)	(176)	(147)	(142)	(142)	(95)
Insecta	9%	14%	46%	59%	78%	83%
Fish Flesh	2%	16%	3%	1%	0%	1%
Debris	1%	2%	13%	16%	10%	9%
Empty	88%	68%	38%	24%	12%	7%
Totals						
No. Stomachs	***145***	***179***	***163***	***191***	***177***	***109***
Insecta	***10%***	***15%***	***50%***	***66%***	***80%***	***84%***
Fish Flesh	***2%***	***17%***	***3%***	***1%***	***0%***	***1%***
Debris	***1%***	***1%***	***13%***	***13%***	***9%***	***8%***
Empty	***87%***	***67%***	***34%***	***20%***	***11%***	***7%***

Reach Data

The Sammamish River was arbitrarily divided into the following reaches in an attempt to identify longitudinal patterns of juvenile salmonid catch: 1) Lake Sammamish downstream to Marymoor Park (RM 13.0); 2) Marymoor Park downstream to Redmond (RM 10.8); 3) Redmond downstream to Woodinville (RM 5.5); and 4) Woodinville downstream to Lake Washington (RM 0.0). At a minimum, four survey sites were located within each reach (Table 7).

Table 7. Site name, location (approximate river mile), habitat strata, habitat sub-unit, and study reach associated with the 22 juvenile salmonid mainstem margin survey sites, Sammamish River, Washington, 2001.

Site Name	Approximate River Mile	Habitat Strata	Habitat Sub-unit	Study Reach
Rowing Club Nearshore	13.6	Natural	Transition Zone	1
Rowing Club Offshore	13.6	Natural	Transition Zone	1
Tennis Ball	13.2	Natural	Transition Zone	1
Cattail	13.2	Natural	Transition Zone	1
Marymoor Park	13.0	Constructed	Setback Levee w/o LWD	1
Highway 908 Bridge	11.8	Natural	Natural	2
Cold Fusion	11.4	Constructed	Setback Levee w/o LWD	2
Senior Center HEP2	11.3	Constructed	Setback Levee w/o LWD	2
90th Street Bridge HEP2	11.2	Constructed	Setback Levee w/ LWD	2
HEP2 Control	11.2	Natural	Natural	2
Powerline Test	10.8	Constructed	Setback Levee w/ LWD	2
Powerline Control	10.8	Natural	Natural	2
R-Factor Upstream Control	6.8	Constructed	Setback Levee w/ LWD	3
R-Factor Upstream Test	6.8	Natural	Natural	3
R-Factor Downstream Test	6.8	Constructed	LWD	3
R-Factor Downstream Control	6.8	Natural	Natural	3
Little Bear Creek Test	5.5	Constructed	Setback Levee w/o LWD	3
Little Bear Creek Control	5.5	Natural	Natural	3
Bothell Siding Company	4.3	Natural	Natural	4
Cove Site	0.9	Natural	Natural	4
J-Site	0.8	Natural	Natural	4
Kenmore Lumberyard	0.5	Natural	Natural	4

Mean juvenile salmonid catch was highest in Reach 1 and decreased in subsequent reaches of the river (Figure 20). Mean CPUE from Reach 1 was significantly greater than mean catch from Reach 2 (Student-Newman Keuls Multiple Comparison Method; $q=5.53$; $p<0.05$); Reach 3 (Student-Newman Keuls Multiple Comparison Method; $q=4.45$; $p<0.05$); and Reach 4 (Student-Newman Keuls Multiple Comparison Method; $q=4.18$; $p<0.05$). Reach 2 catch indices were greater than both Reach 3 and Reach 4, however, there was not significant differences in juvenile salmonid catch between the three remaining reaches (Student-Newman Keuls Multiple Comparison Method; $p>0.05$). Beginning on 11 April, Reach 1 mean juvenile salmonid catch indices were consistently greater than those from the other three reaches (Figure 21).

When examined at the reach level, juvenile salmonid CPUE information followed the same seasonal patterns as was exhibited by total catch data. Juvenile salmonid CPUE was dominated by sockeye salmon fry in February through March and into early April. This continued until late April, when coho fry composed the majority of the catch. By 20 May, chinook were contributing to more than 40% of the total catch at each reach. By late June and into July, coho, chinook, and sockeye salmon, and cutthroat trout were all fairly equally distributed in the catch. Juvenile chinook catch indices peaked in late May and early June, reaching an individual peak (CPUE = 0.0185) in Reach 3 on 20 May (Figure 22). Catch rates of juvenile coho followed a similar pattern, peaking overall in late April and early May, and reaching an individual peak (CPUE = 0.0403) in Reach 1 on 8 May (Figure 23). Sockeye, on the other hand exhibited an earlier peak overall, and an individual peak (CPUE = 0.0849) on 19 March in Reach 1 (Figure 24).

Site Data

Mean juvenile salmonid catch was greatest (CPUE = 0.0725; std. dev. = 0.036) at the Tennis Ball Site, a Transition Zone Site located in Reach 1 (Figure 25). Mean CPUE was lowest (CPUE = 0.0052; std. dev. = 0.004) at the R-Factor Upstream Control Site located in Reach 3 (Figure 25). With notable exceptions, sites located in Reaches 1 and 2 generally exhibited higher catch indices than their counterparts located in Reaches 3 and 4 of the Sammamish River. Peaks in individual species at each site are presented in Appendix A (Tables A11 through A-22; Figures A-1 through A-22). Juvenile chinook CPUE peaked (CPUE = 0.0371) at the Cold Fusion Site (Reach 2) on 20 May. Meanwhile juvenile coho catch peaked at Marymoor Park (CPUE = 0.0849) on 20 May; sockeye peaked at the Tennis Ball Site (CPUE = 0.3515) on 19 March. Cutthroat trout catch indices were consistently high throughout the season at the Powerline Test Site.

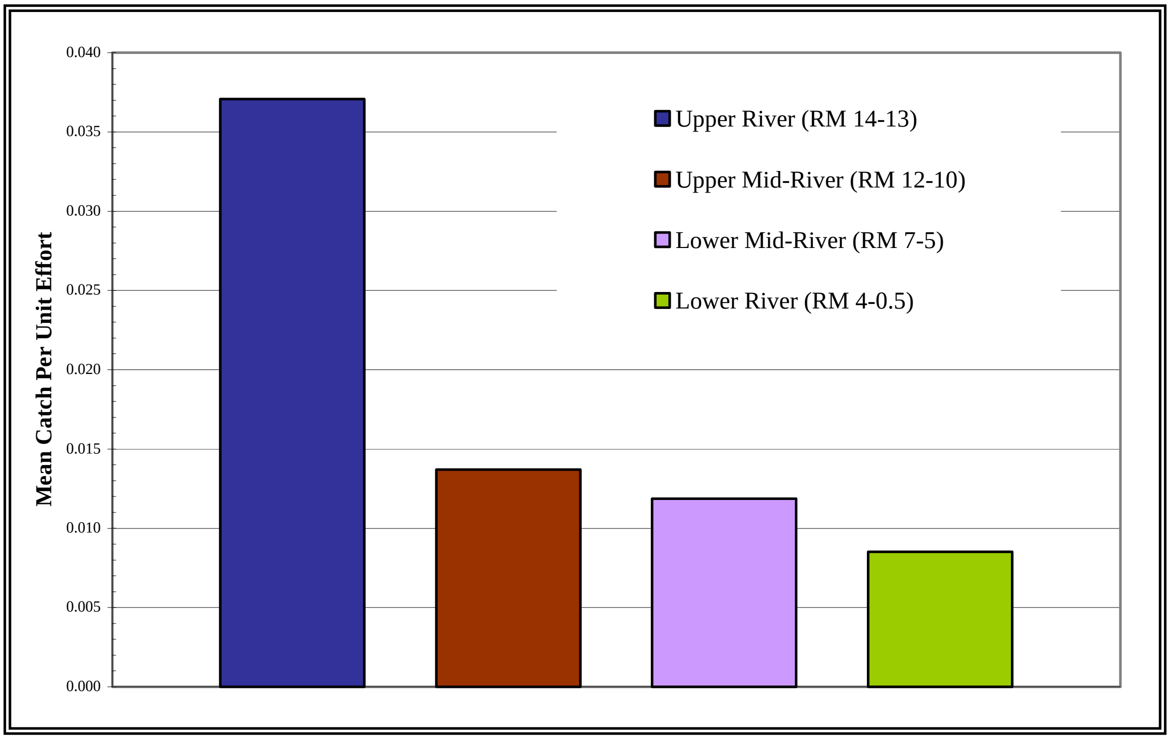

Figure 20. Mean juvenile salmonid catch per unit effort (CPUE) for 4 reaches of the Sammamish River, Washington 2001.

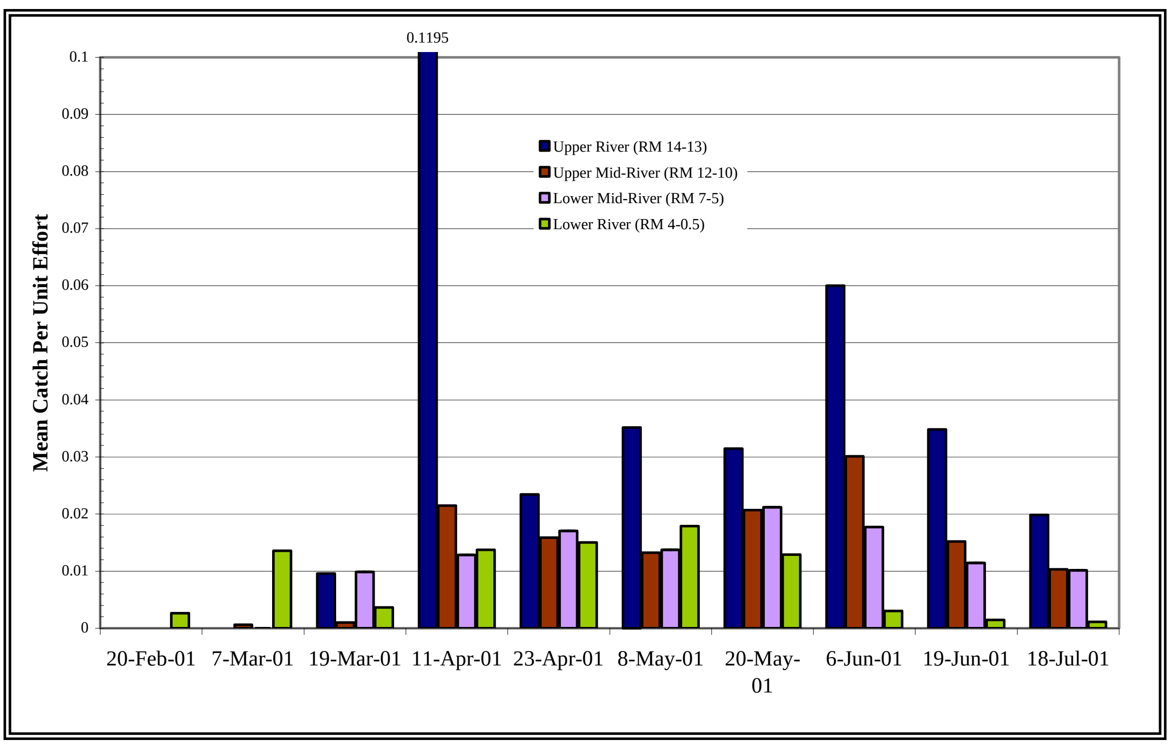

Figure 21. Mean juvenile salmonid catch per unit effort (CPUE) on each survey date for 4 reaches of the Sammamish River, Washington 2001.

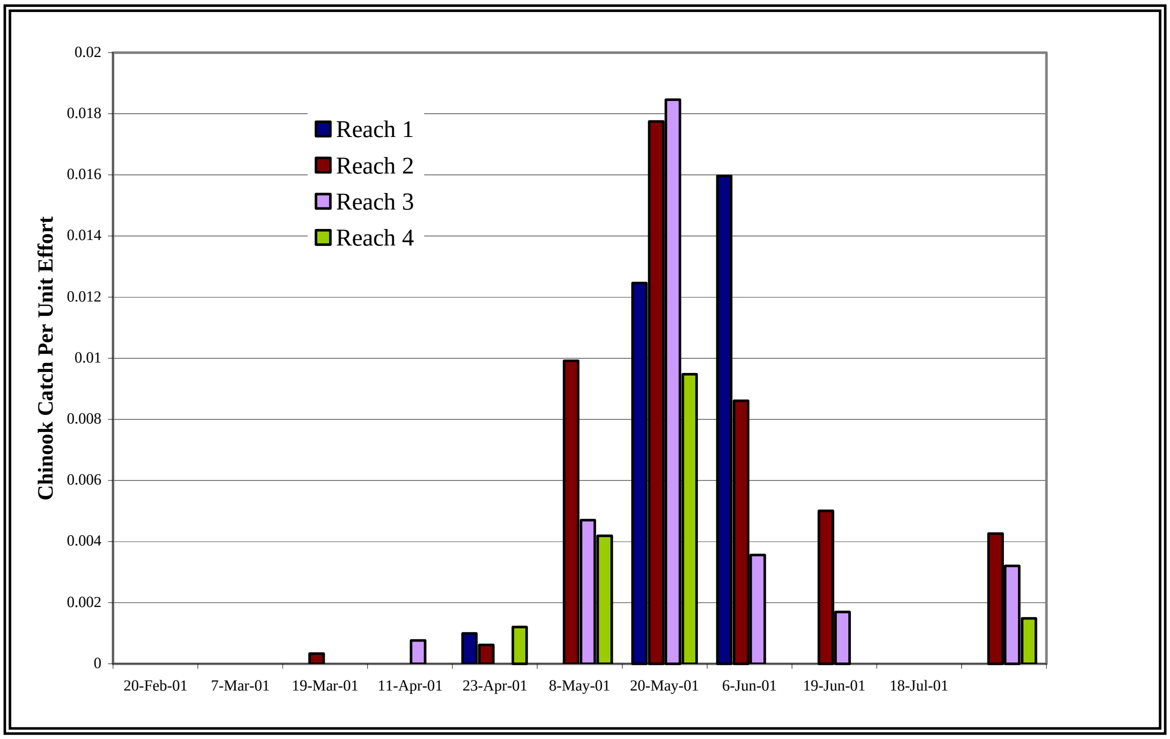

Figure 22. Mean juvenile chinook catch per unit effort (CPUE) for 4 reaches of the Sammamish River, Washington 2001.

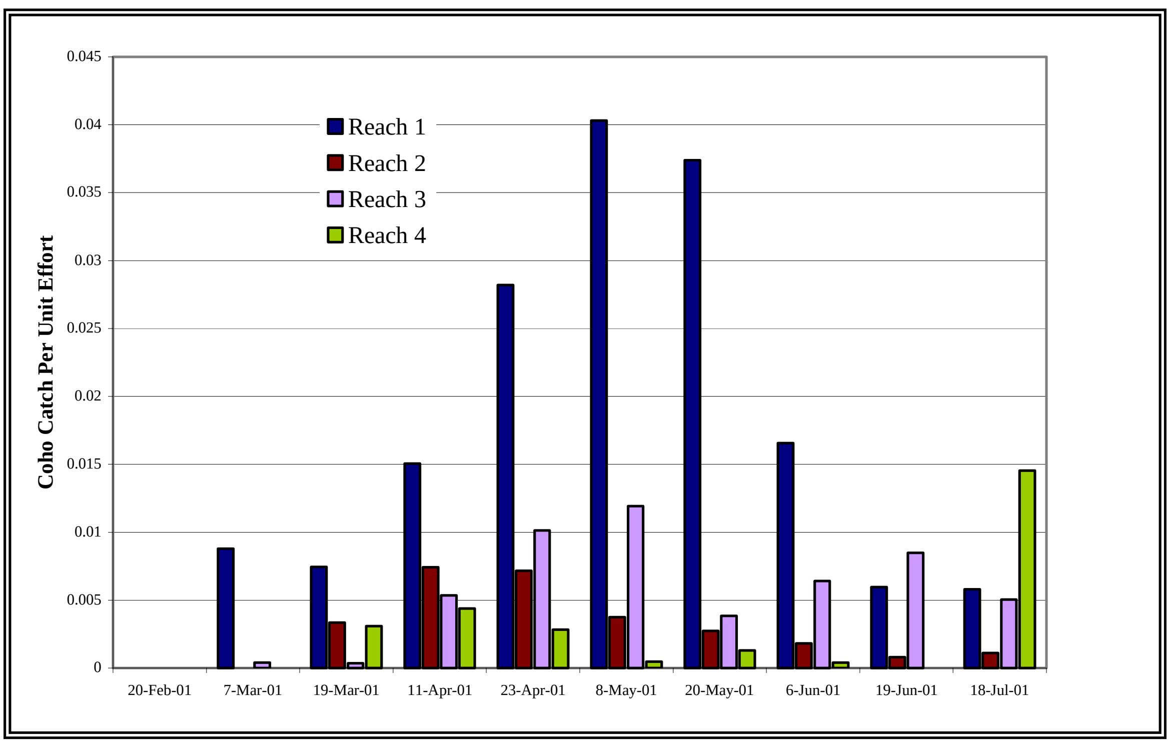

Figure 23. Mean juvenile coho catch per unit effort (CPUE) on each survey date for 4 reaches of the Sammamish River, Washington 2001.

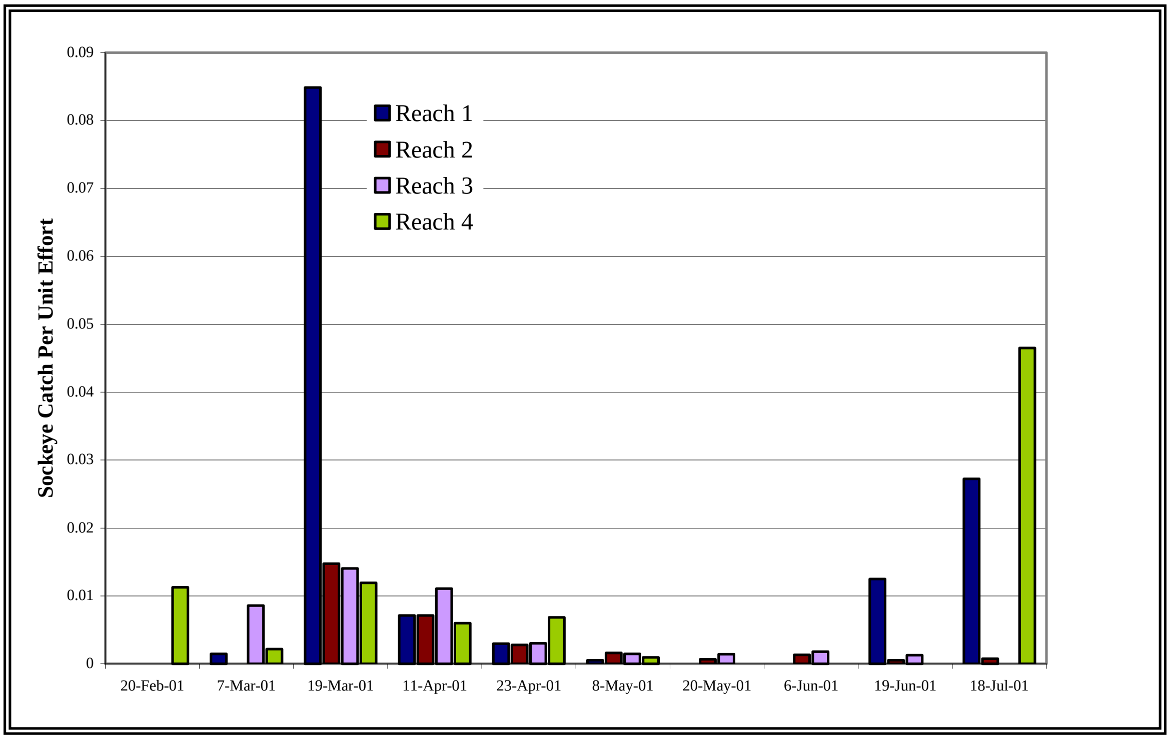

Figure 24. Mean juvenile sockeye catch per unit effort (CPUE) for 4 reaches of the Sammamish River, Washington 2001.

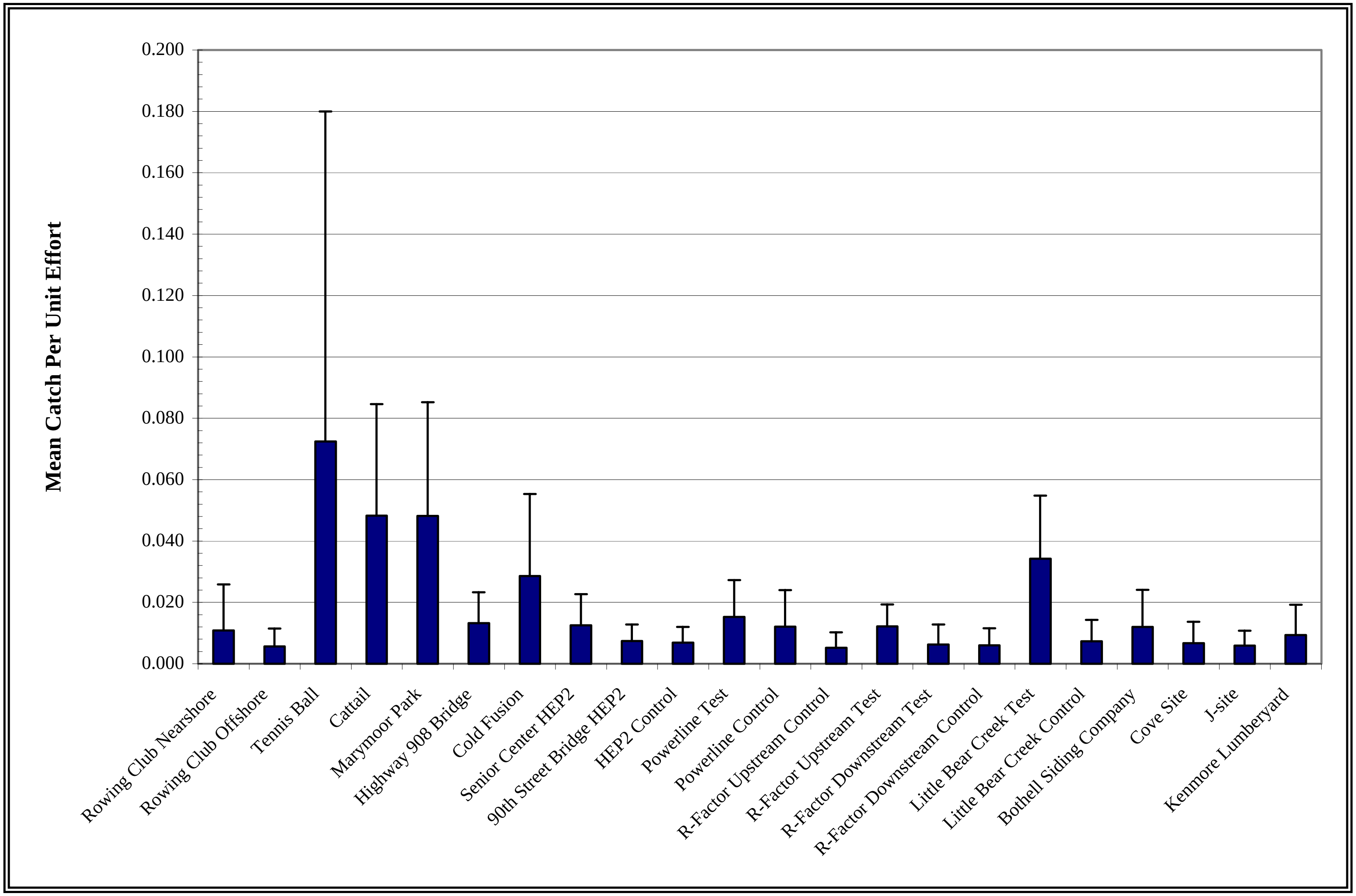

Figure 25. Catch per unit effort indices with standard deviation for 22 juvenile salmonid nighttime survey sites in the Sammamish River, Washington, 2001.

4.1.2 Juvenile Salmonid Use of Created Habitats

A post-treatment experimental design was used to determine the response of juvenile salmonids to different enhancement/restoration techniques, whereby comparisons were made between test and control sites over time (Table 7). These comparisons were replicated in different reaches of the Sammamish River, with the exception of large woody debris without setback, which was only tested in Reach 3. Juvenile salmonid catch indices were consistently greater than their associated control sites at sites containing setback levees without large woody (Figure 26). This difference was apparent at both the site level (Marymoor Park, Cold Fusion, Senior Center HEP2, and Little Bear Creek Test), with all sites combined, and between reaches. Significantly more juvenile salmonids were captured at the Marymoor Park Site (Reach 1) when compare to its control (Highway 908 Bridge) (Mann-Whitney Rank Sum Test; T=135.0; P=0.03). A similar relationship existed for the Cold Fusion Test and Control Site (Mann-Whitney Rank Sum Test; T=80.0; P=0.05) and the Little Bear Creek Test and Control site (t-Test; t=3.92; P=0.001), which are located in Reaches 2 and 3 of the Sammamish River, respectively. An additional setback levee comparison was conducted at the recently constructed Riverwalk HEP2 Site. The CPUE of the Senior Center HEP2 Site was larger than HEP2 Control, however this difference was not significant (Mann-Whitney Rank Sum Test; T=121.0; P=0.2412). When combined, juvenile salmonid catch indices of all setback levee test sites were significantly greater than their control sites (Mann-Whitney Rank Sum Test; T=139.5; P=0.01) (Figure 26).

Juvenile salmonid catch indices from sites containing both large woody and a setback levee were also greater than their associated controls at all sites and on most survey dates (Figure 27). Juvenile salmonid CPUE was not significantly different at the site level between the test and control at 90th Street Bridge HEP2 (t-Test; t=0.228; P=0.822) located in Reach 2; Powerline Test and Control (t-Test; t=0.582; P=0.568) located in Reach 2. The difference in juvenile salmonid catch was significantly different for setback levees containing large woody debris in Reach 3 at the R-Factor Upstream Test and Control Site (t-Test; t=2.51; P=0.0218), however. When combined, juvenile salmonid catch indices of all setback levee test sites containing large woody debris were not significantly greater than their control sites (t-Test; t=1.21; P=0.2422) (Figure 27).

Juvenile salmonid use of large woody debris without setback levees was only examined at one location in the Sammamish River. Catch of juvenile salmonids from the R-Factor Downstream Test Site was greater than the control site; however the difference was not great enough to reject the possibility that the difference is due to random sampling variability (t-Test; t=0.0884; P=0.9306).

In addition, we combined the data from all sites to test for overall differences in juvenile salmonid response to the habitat enhancement/restoration techniques in the Sammamish River. Juvenile salmonid catch was consistently greater (except on 20 February when only eight salmonids were captured) at levee setback sites that did not contain large woody debris compare to both setback levee with large woody debris and sites that only contained large woody debris (Figure 29). Mean catch of juvenile salmonids ranged from a high of 0.0647 (std. dev.=0.023) on 20 May (setback levee w/o large woody debris) to a low of zero on 20 February (large woody debris only and setback levee w/o large woody debris). Mean juvenile salmonid CPUE was significantly different at setback levee sites that did not contain large woody debris when compared to setback levee sites containing large woody debris (Mann-Whitney Rank Sum Test; T=71.0; P=0.0113) and the large woody debris site (Mann-Whitney Rank Sum Test; T=144.5; P=0.0032). There was not a significant difference in juvenile salmonid catch between setback levee and large woody debris sites and the site containing only large woody debris (t-Test; t=1.75; P=0.0977). Results from the last test (setback levee w/ large woody debris vs. large woody debris) should be interpreted cautiously; because of low power (0.2598), there is a chance that the observed difference is significant (Type II error).

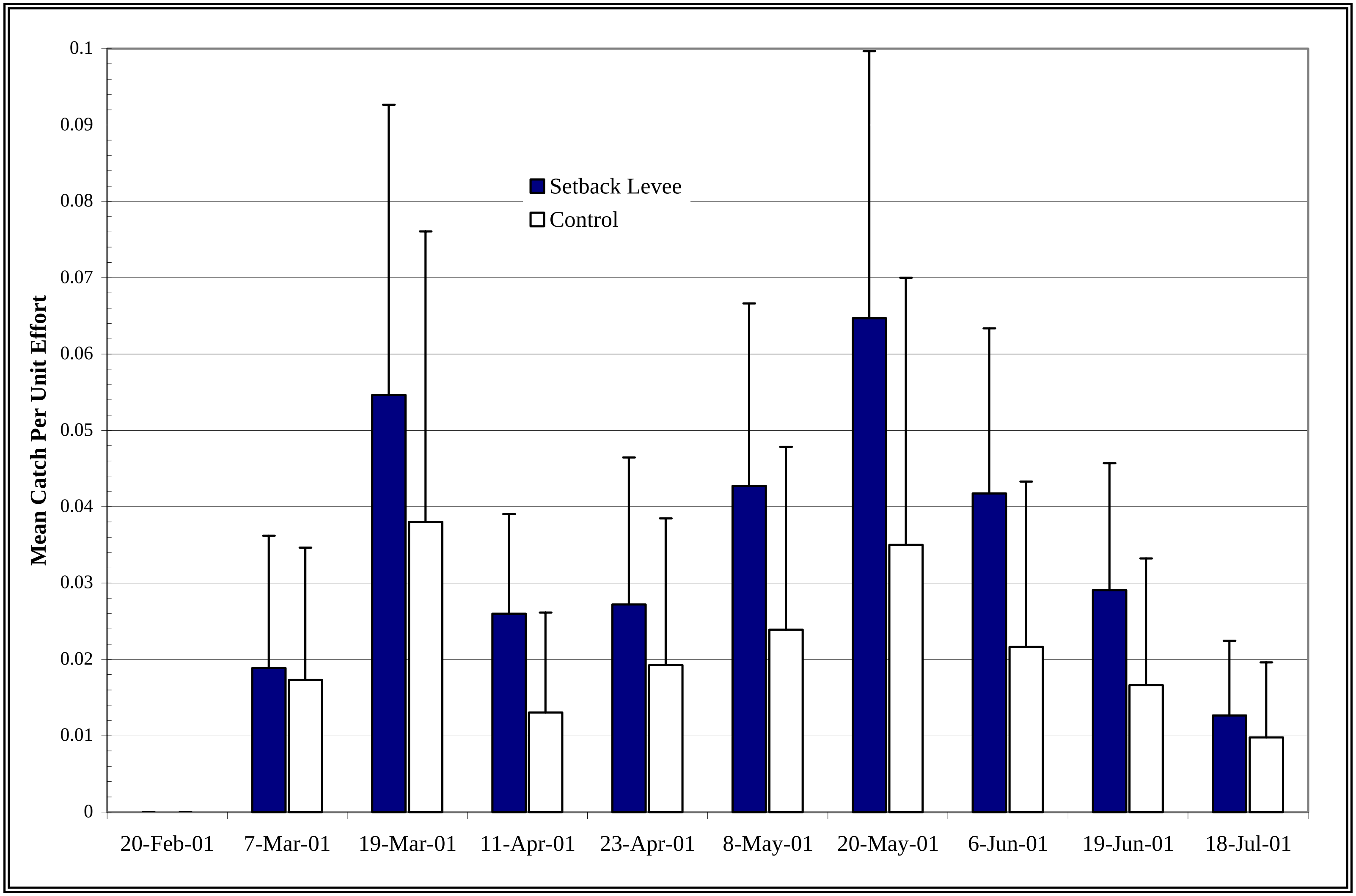

Figure 26. Catch per unit effort indices with standard deviation for setback levee test (shaded) and control (clear) survey sites in the Sammamish River, Washington, 2001.

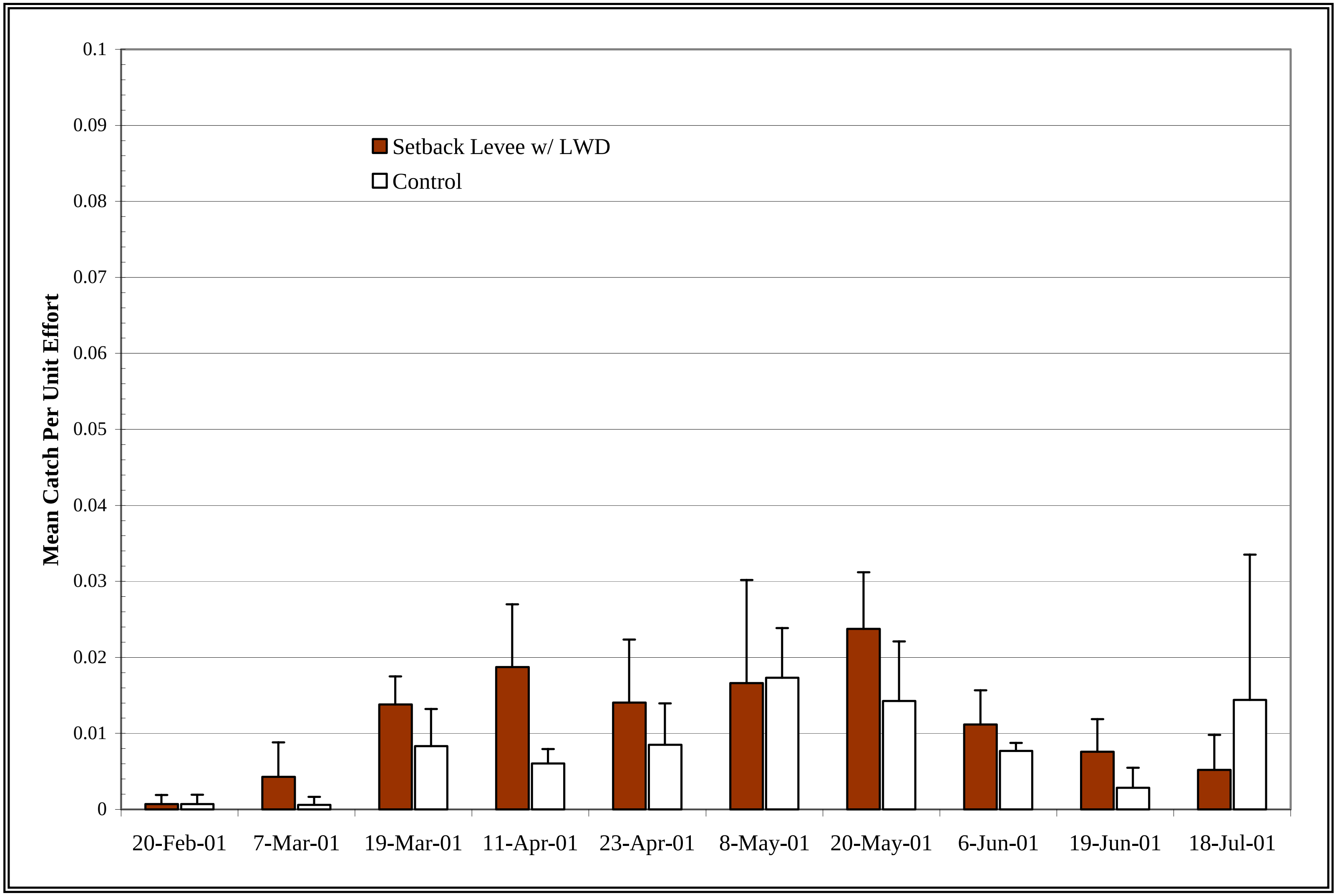

Figure 27. Catch per unit effort indices with standard deviation for setback levees containing large woody debris test (shaded) and control (clear) survey sites in the Sammamish River, Washington, 2001.

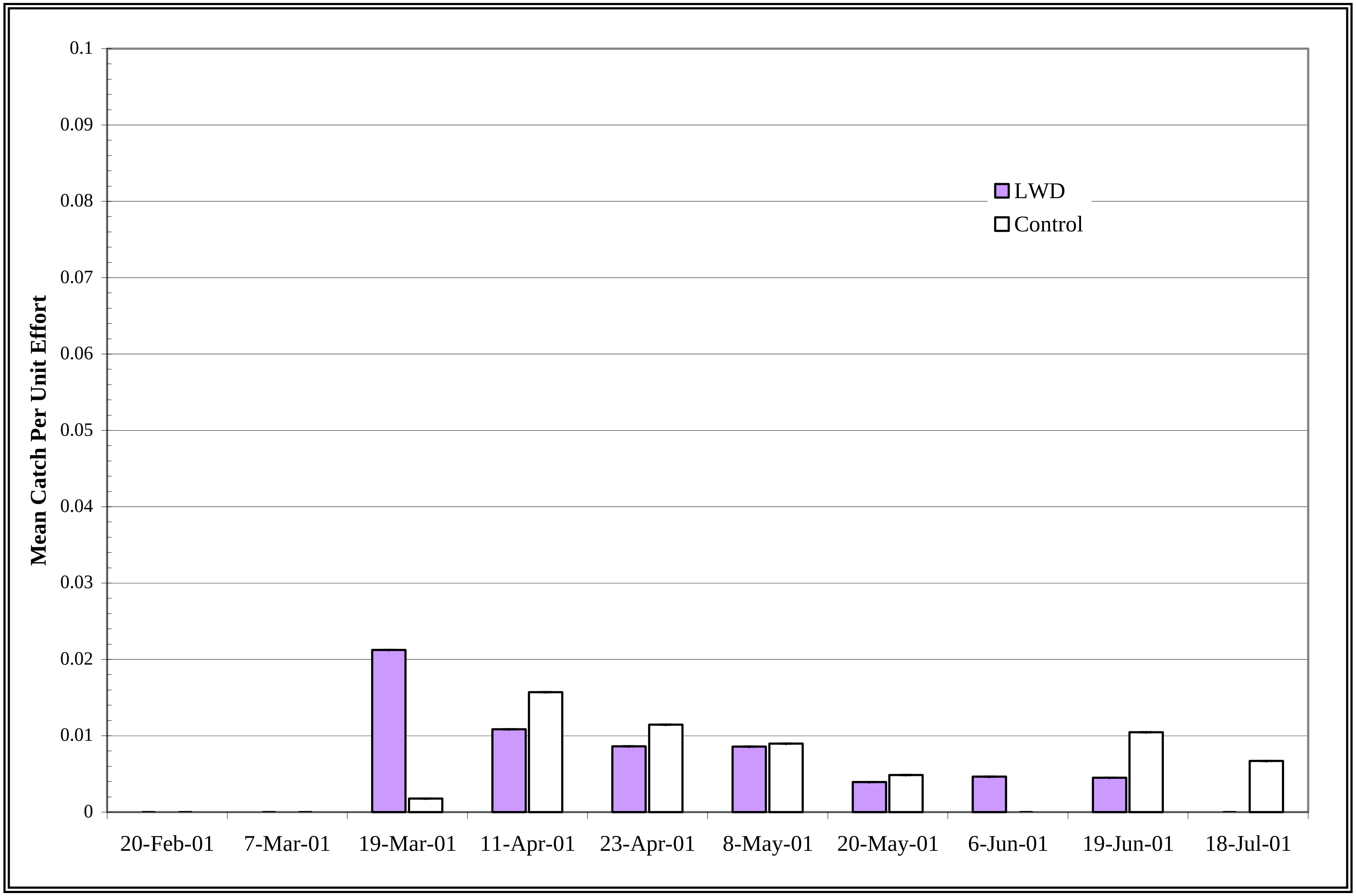

Figure 28. Catch per unit effort indices for large woody debris test (shaded) and control (clear) survey sites in the Sammamish River, Washington, 2001.

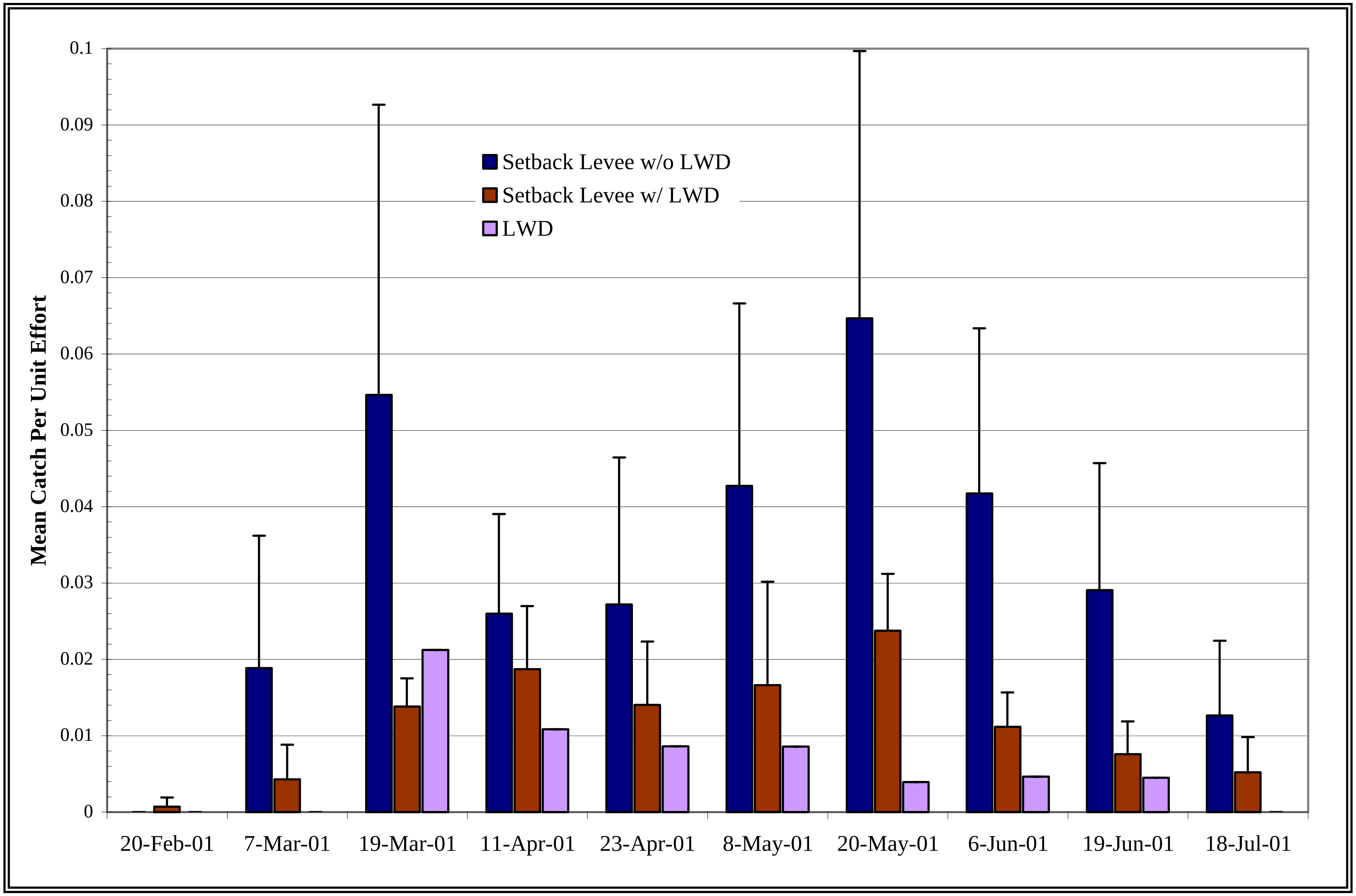

Figure 29. Catch per unit effort indices with standard deviations for setback levees, setback levees containing large woody debris, and large woody debris survey sites in the Sammamish River, Washington, 2001

4.1.3 Juvenile Salmonid Use of Transition Zone

Four study sites (two near the Rowing Club Boat Launch and two downstream from the weir) were established within Marymoor Park to identify important naturally occurring habitat types for juvenile salmonids within the Transition Zone of the Sammamish River (Reach 1; Table 7). The sites located at the Rowing Club Boat Launch were monitored to examine juvenile salmonids use of Eurasian water milfoil (Rowing Club Offshore) relative to bank habitats (Rowing Club Nearshore). Sites located downstream from the weir were monitored to determine juvenile salmonid use of willow riparian canopy (Tennis Ball) in relation to cattail riparian canopy (Cattail). Over the entire study period, juvenile salmonid catch was highest at the Tennis Ball Site (mean=0.0725; std. dev.=0.1075) and lowest at the Rowing Club Offshore Site (mean=0.0056; std. dev.=0.0059). Paired comparisons indicate that while juvenile salmonid catch was higher at the Tennis Ball Site, there was not a significant difference from juvenile CPUE at the Cattail Site (Mann-Whitney Rank Sum Test; T=105.5; P=1.000) (Figure 30). Likewise, there was not a significant difference between the CPUE at the Rowing Club Nearshore Site when compared to the Rowing Club Offshore Site (t-Test; t=1.03; P=0.3164) (Figure 30). When data from the Transition Zone are combined, juvenile salmonid catch was significantly higher at sites located downstream of the weir (Cattail and Tennis Ball) when compare to sites located near the Eurasian Milfoil (Rowing Club Sites) (Table 8).

Table 8. Student-Newman-Keuls multiple comparison of mean juvenile salmonid CPUE from four survey site located in the Transition Zone of the Sammamish River, Washington, 2001 (+ indicates that the first survey site was significantly greater than the second survey site; - indicates there is no significant difference).

Comparison	**q**	**P-value**	**Significant**
Tennis Ball vs Rowing Club Nearshore	5.173	<0.05	+
Cattail vs Rowing Club Nearshore	7.537	<0.05	+
Tennis Ball vs Rowing Club Offshore	4.193	<0.05	+
Cattail vs Rowing Club Offshore	5.460	<0.05	+

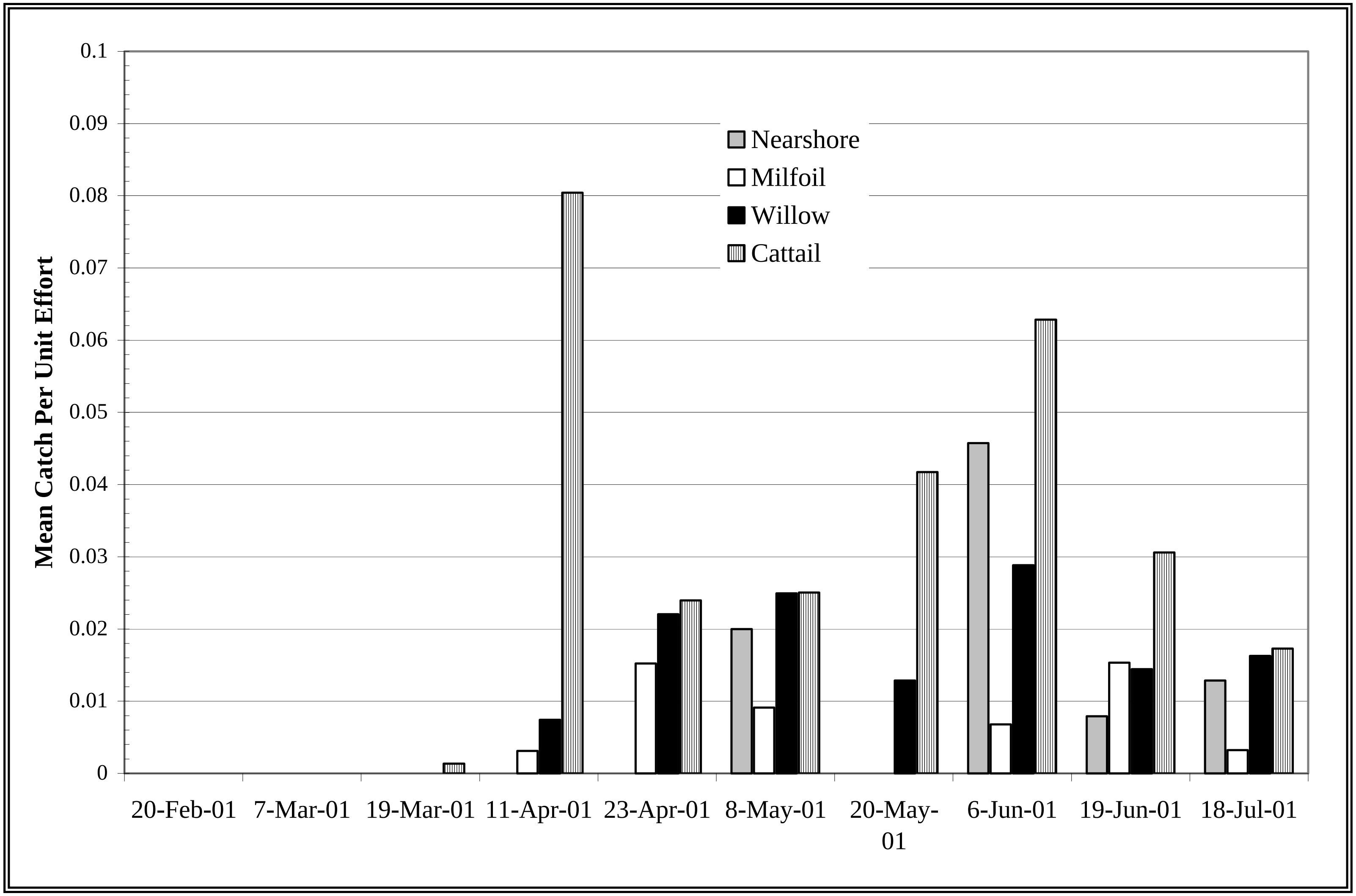

Figure 30. Mean juvenile salmonid catch per unit effort (CPUE) for 4 survey sites located in the Transition Zone of the Sammamish River, Washington 2001.

4.1.4 Non-Salmonid Species

In addition to salmon, trout, and whitefish, 5,803 non-salmonids were captured during nighttime electrofishing surveys in the Sammamish River. Non-salmonid species in order of decreasing capture frequency were: prickly sculpin Cottus (*Cottus asper*); three-spine stickleback (*Gasterosteus aculeatus*); northern pikeminnow (*Ptychocheilus oregonensis*); largescale sucker (*Catostomus macrocheilus*); yellow perch (*Perca flavescens*); bluegill (*Lepomis macrochirus*); river lamprey (*Lampetra ayresi*); western brook lamprey (*L. richardsoni*); Pacific lamprey (*L. tridentatus*); redside shiner (*Richardsonius balteatus*); smallmouth bass (*Micropterus dolomieui*); brown bullhead (*Ictaluris nebulosus*); pumpkinseed (*L. gibbosus*); largemouth bass (*M. salmoides*); longnose dace (*Rhinichthys cataractae*); peamouth (*Mylocheilus caurinus*); and loach (*Misgurnus spp.*) (Appendix A; Table A-23). Among the non-salmonid species, catch indices of prickly sculpin, three-spine stickleback, and northern pikeminnow were more than 400% greater than the catch indices of any other single non-salmonid species (Figure 31). Together, the three species accounted for more than 96% of the total non-salmonid catch.

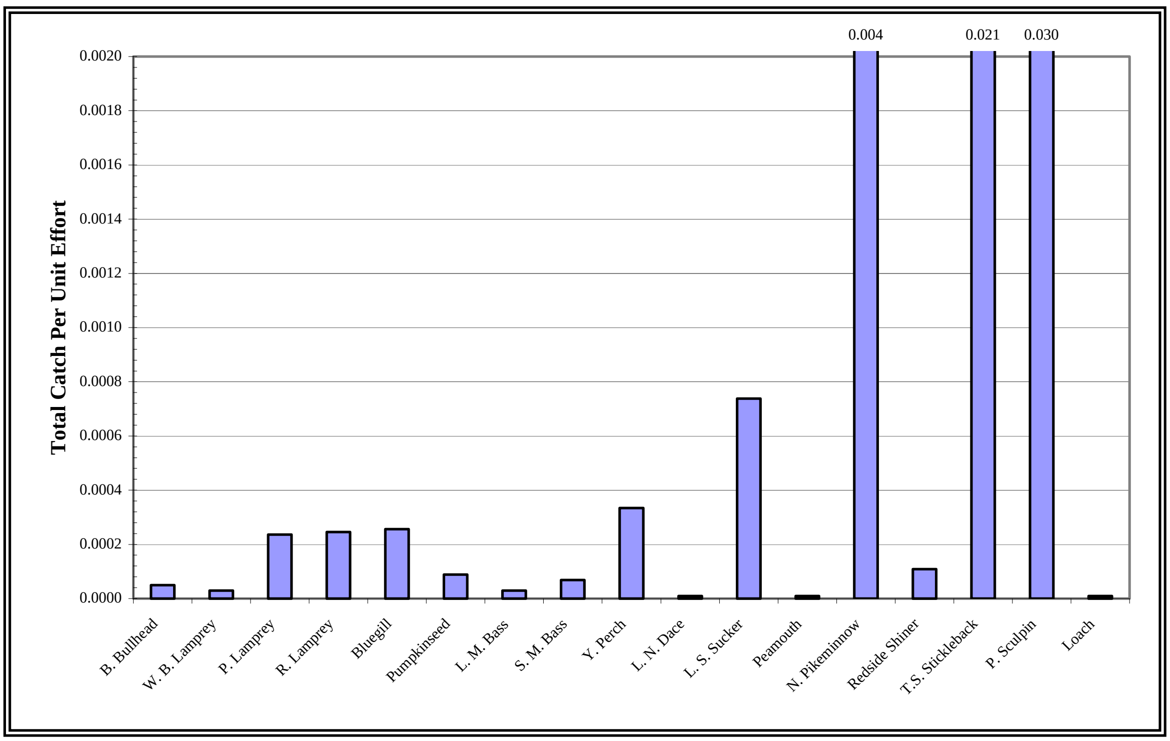

Figure 31. Total catch per unit effort for all non-salmonid species captured in the Sammamish River, Washington, 2001.

4.2 FLOW AND WATER TEMPERATURE DATA

Daily discharge remained greater than 150 cfs until 6 July (mean = 258 cfs; std. dev. = 69) (Figure 32). Discharge peaked briefly (436 cfs) in the Sammamish River on 12 June, and remained fairly constant (~250 cfs) throughout the study period of February through mid-June 2001. Discharge decreased rapidly in late June and July, reaching a low of 89 cfs by 14 July.

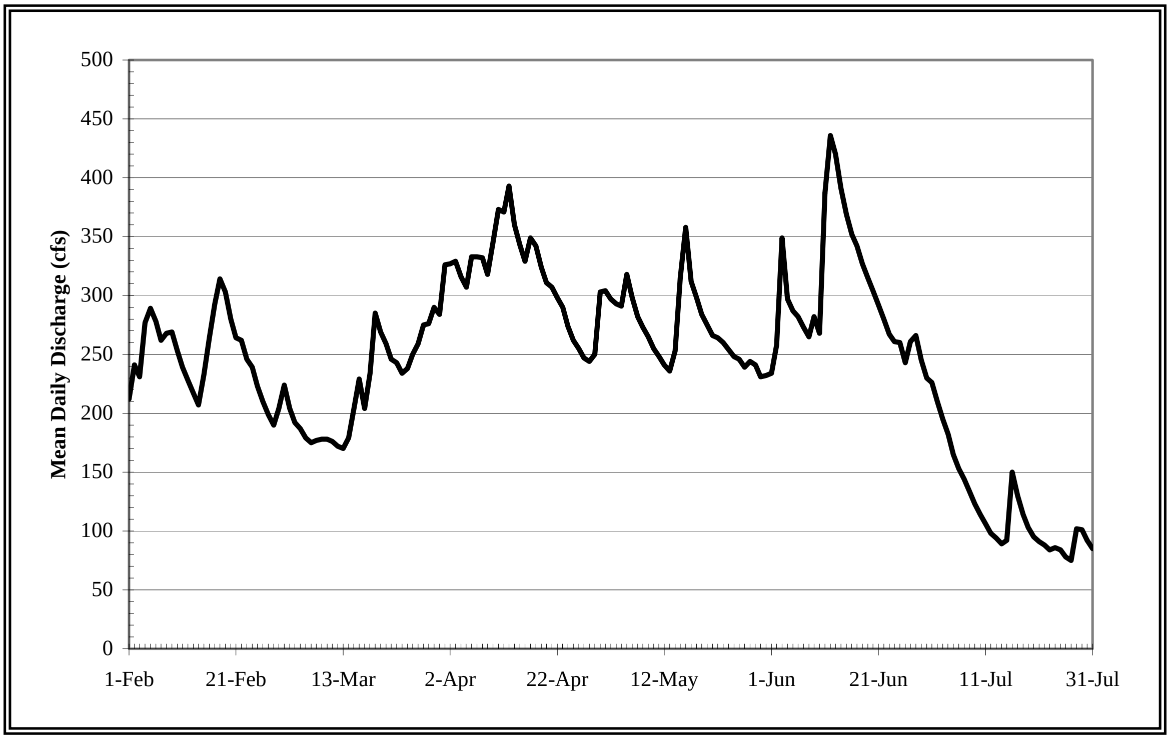

Figure 32. Mean daily discharge (cfs) as measured in the Sammamish River near Woodinville, Washington, 2001 (USGS Gage 12125200; RM~5.5).

Water temperature data recorders were placed into the Sammamish River at the following site locations; Rowing Club Nearshore, Marymoor Park, Highway 908 Bridge, Powerline Control, R-Factor Downstream Control, Little Bear Creek Control, and J-Site (Appendix B; Figures B-1 through B-7). In general, mean daily water temperatures were approximately 7-8°C when the study period began (18 February) and slowly increased, reaching a maximum of 21-22°C in early July, and then decreased slowly until 18 July (Figure 33). Overall, daily water temperatures were the highest (mean = 14.3°C) at the study sites located near the Rowing Club (RM 0.5) and lowest (mean=13.6) at the Powerline sites (RM 10.8) and at the

Little Bear Creek Sites (RM 5.5). The highest maximum daily water temperature (23.37°C) was recorded at the J-Site near Kenmore (RM 0.8). Median daily water temperatures were not significantly different among any of the survey sites (Kruskal-Wallis One Way Analysis of Variance on Ranks; P=0.6258). Likewise, maximum (Kruskal-Wallis One Way Analysis of Variance on Ranks; P=0.8555) and minimum (Kruskal-Wallis One Way Analysis of Variance on Ranks; P=0.1789) daily water temperatures were not significantly different between the study sites.

4.3 PHYSICAL HABITAT SURVEYS

With a few exceptions, the majority of the juvenile salmonid survey sites had similar habitat features (Appendix B; Table B-5). Overall, mean depth and velocity, dominant and sub-dominant substrate, and riparian vegetation were similar between study sites. Some exceptions occurred between test and control sites. Control sites were deeper and slower than their corresponding test sites. Mean depth of setback levee sites was less than setback levee sites that contained large woody debris. The sites within the transition zone had relatively more complex riparian canopy. The slope or bank angle of control sites was much higher than either levee setback sites or levee setback sites containing large woody debris. Except for the sites located at the Redmond Riverwalk HEP2 Project and at R-Factor, substrate was generally composed of silt, sand, or a combination of the two (Table B-1).

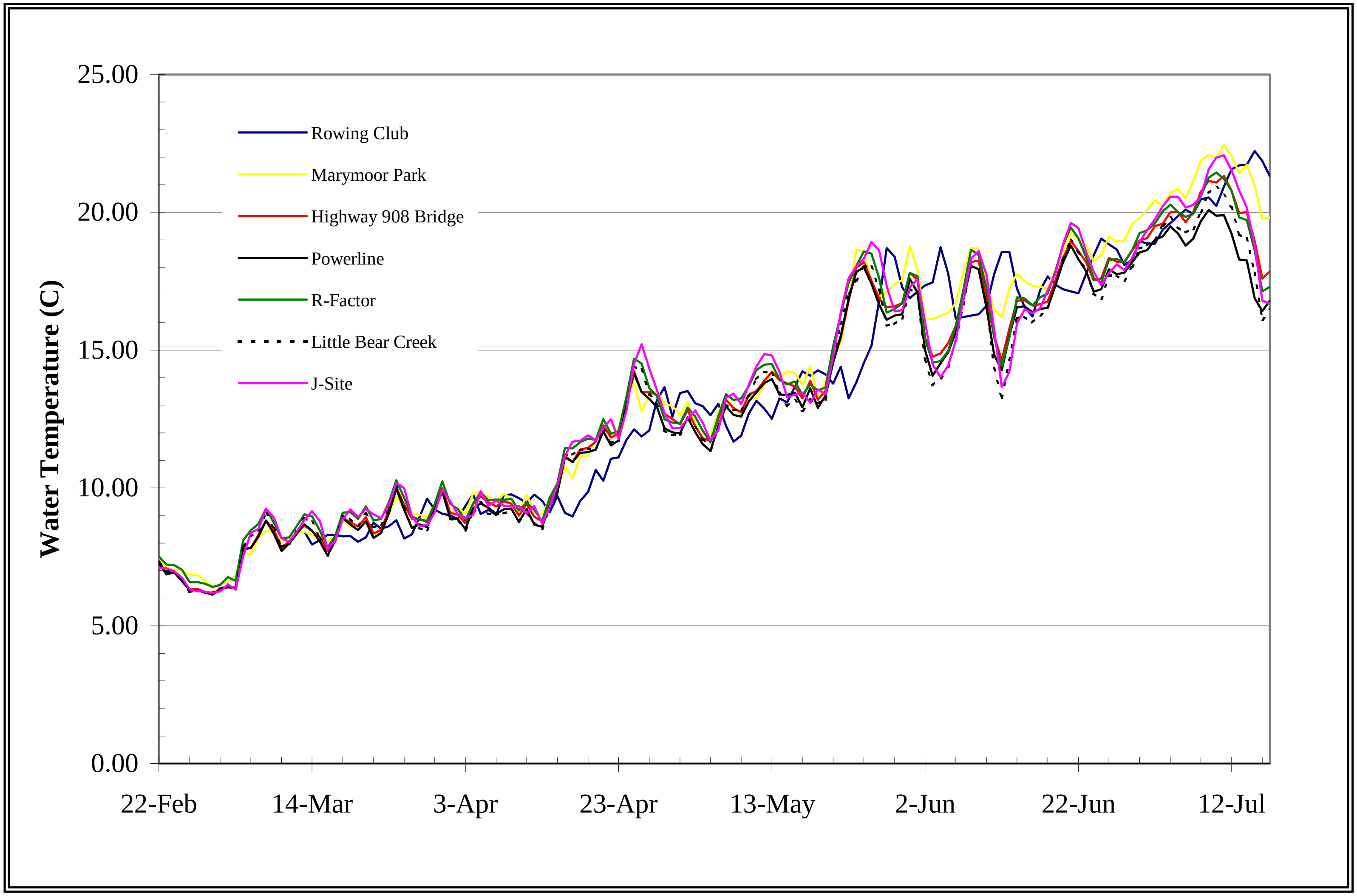

Figure 33. Mean daily water temperatures recorded at seven juvenile salmonid survey sites in the Sammamish River, Washington 2001.

5. DISCUSSION

When species become protected under the Endangered Species Act (ESA), pressure mounts from private and public sources to reduce the rate of species decline, and where feasible, contribute to population recovery. Often times, the initial step in the recovery process is formulation and implementation of either basin-specific or statewide recovery plans for threatened or endangered species. The ESA stipulates that critical habitat of the threatened or endangered species must be identified and protected. This is often a daunting task when dealing with species that may migrate thousands of miles during their lifetime. The majority of the recovery plans for chinook salmon in the Pacific Northwest concentrate on freshwater life cycle components. Stream restoration projects are invariably linked to most salmonid recovery plans. Stream restoration, typically defined as returning a stream to some undisturbed level (Kauffman et al. 1997; Roper et al. 1997), is not feasible in many urban settings because of irreversible human impacts. With this in mind, ensuring that the dynamics of system processes are operating so that the ecosystems can properly function is often the goal of many restoration or enhancement programs.

Unlike other streams in Puget Sound, the entire Sammamish River is a relatively large, low gradient stream, supporting a wide array of both native and non-native fish species. Situated between Lake Sammamish and Lake Washington, and Puget Sound, the Sammamish River is an important habitat component of chinook salmon that are protected under the ESA. Placement of wood and boulders in streams to increase the fish numbers has been occurring since the 1930s (Meehan 1991; Reeves et al. 1991). Large woody debris and boulder placement has been proposed as techniques to enhance or restore the instream habitat of the Sammamish River. Habitat enhancement structures such as log weirs, lateral log jams, debris catchers, and boulder clusters are common management techniques to improve fish habitat in an effort to compensate for decades of anthropogenic impacts (Kauffman et al. 1997; Slaney and Zaldokas 1997). Unfortunately, many projects that were initiated early on did not address the effectiveness of their techniques, or simply lacked the funding to quantify the response of salmonids to enhancement measures (Kauffman et al. 1997; Williams et al. 1997). Recently, however, regional scientists have recognized the importance of monitoring not only the abiotic (e.g., pool formation), but the biotic (juvenile salmonid abundance) response related to stream enhancement or restoration projects (Reeves et al. 1997). Many studies have involved monitoring the response of juvenile salmonids to enhancement projects constructed in either small, low gradient streams in forested watersheds, or streams with higher gradient than the Sammamish River (Roni 2001).

The objective of this study was to develop a process that could effectively monitor juvenile salmonid response to several types of stream enhancement/restoration techniques that are currently used in the Sammamish River. The results of this study will allow local planners to develop effective enhancement/restoration techniques specific to the Sammamish River based on the channel and riparian environment and its hydraulic characteristics.

The Sammamish River does not afford researchers the opportunity to utilize visual observations, beach seining, or trapping as sampling techniques because of underlying physical factors. Due to low water velocity, steep banks, and chronic high turbidity, the preferred sampling technique was one-pass electrofishing using straight, direct current. During the 2001 study period, we collected 1,627 juvenile salmonids in 22 study sites. All study specimens were collected using a backpack electrofishing unit. Although we monitored these fish for only about 30 minutes before releasing them back into their site of capture, we observed only 3 immediate injuries/mortalities (2 sockeye and 1 whitefish), or less than one-fourth of one percent. Likewise in 2000 during our pilot study, we captured 251 juvenile salmonids using the backpack electrofishing technique without any immediate injuries/mortalities. Similar studies have occurred in the Green River over the past four years in which more than 20,000 juvenile salmonids have been captured using this technique with similar results (immediate injuries/mortalities < 0.25%) (Jeanes and Hilgert 2001).

Schill and Elle (2000) indicate that severity of electroshock-induced hemorrhages increases initially and begins to decline by 15 d postshocking, resulting in few (<2%) long-term detrimental impacts to the rainbow trout (mean length ~ 270 mm) that they studied. Fredenberg (1992) found that electrofishing using smooth (i.e., straight) electrical waveforms injured significantly fewer rainbow trout and brown trout (*Salmo trutta*) in Montana river systems than using other electrical waveforms (i.e., rectified AC, pulsed DC, and CPS). In a study to evaluate the incidence of sub-lethal spinal injuries on fish that were not visibly harmed by electrofishing, Dalbey et al. (1996) found that when X-rayed, approximately 37 percent of the fish suffered from spinal injuries. None of these fish displayed visible injuries, but were larger (153-388 mm FL) than the fish we captured in the middle Sammamish River. Like Fredenberg (1992), Dalbey et al. (1996) showed that smooth DC injured fewer fish (12%) than pulsed DC (40-54%). Injury and severity of injury rates were positively correlated with fish length ($r = 0.70$-0.83, $P < 0.02$) (Dalbey et al. 1996). Hollender and Carline (1994) reported injury rates of 14 percent on small (<125 mm TL) brook trout (*Salvelinus fontinalis*) captured using backpack electrofishing units. However, unlike Dalbey et al. (1996) and Fredenberg (1992), they did not test smooth DC current, which could have lowered the injury rate to less than 14 percent (Hollender and Carline 1994).

In light of these studies and keeping within the constraints of ESA guidelines, we attempted to minimize injury to juvenile salmonids by several methods. Electrical current was supplied by using two hand-held wands as the anode and cathode, instead of the traditional format of a hand-held "wand" anode, and a "rat-tail" cathode (see Nielsen 1998 photographs). Juvenile fish captured using this technique were exposed to a brief electrical current before they were captured in the dip net. In addition, waters suitable to juvenile salmonids are much shallower and low velocity than adult fish typically inhabit. This enabled us to utilize brief periods of electrical current, capture the fish quickly, and transfer them to a live container to avoid excessive exposure to electrical current.

Often, stress, not electrofishing injury, has been correlated to the reduced survival of juvenile salmonids exposed to electrofishing (Nielsen 1998). Other factors such as operator expertise, frequency, voltage level, band width and pulse rate, and forms of electrical current are known to affect injury rates while employing this capture technique (Dalbey et al. 1996). As in 2000, guidelines for electrofishing waters containing salmonids listed under the Endangered Species Act (NMFS 1998) were strictly adhered to during the 2001 field season. "Smooth or straight" DC current has been used and will continue to be used for this project. "Smooth" DC current at voltages of less than 400 were effective in the waters of the Sammamish River, and are within the standards cited by the National Marine Fisheries Service for backpack electrofishing waters containing fish species that are listed under the endangered species act (NMFS 1998), and State of Washington Scientific Collection Permit Application guidelines.

As a whole, catch rates of juvenile salmonids in the Sammamish River were lower than original expectations. As a comparison, catch rates of juvenile salmonids in the Green River are more than a level of magnitude higher compared to the Sammamish River. While not directly comparable because of many factors (e.g., size of river, adult escapement, and species assemblage), the level of difference that we encountered, combined with low recapture rates indicate that juvenile salmonids do not reside in the Sammamish River for extended periods of time. It appears that relatively more juvenile salmonids utilize the upper reaches of the Sammamish River for longer time periods when compared to reaches located downstream from the City of Redmond. More than 58 percent of the chinook captured in the Sammamish River originated from the Issaquah Creek Hatchery suggesting that the majority of the juvenile salmonids in the Sammamish River originate and rear in tributaries and use the river as a migration corridor, not for extended rearing purposes. Jeanes and Hilgert

(1999) found few areas in the Sammamish River that represent adequate spawning habitat, which suggests that a large percentage of the salmonids that were captured originated either from Bear Creek or Issaquah Creek, the two largest tributaries in the Sammamish watershed.

This does not undermine the important role of the Sammamish River during the freshwater lifecycle of anadromous salmonids. The importance of mainstem habitat for juvenile chinook salmon rearing and migration is becoming more evident throughout the Pacific Northwest (Edmundson et al. 1968; Reimers et al. 1971; Thedinga et al. 1988; Hayman et al. 1996; USFWS et al. 1999; R. Peters, USFWS, pers. comm.). Chinook salmon fry preferred the edge of the stream where low water velocities and structural cover was present in the Trinity River, California (USFWS et al. 1999). As they became larger, juvenile chinook became less dependent on edge habitats and moved into areas containing higher water velocities. A similar niche shift was observed on the middle Green River (Jeanes and Hilgert 2001). In 2000, chinook alevins (i.e., yolk attached) were observed using only the shallow mainstem margins in the middle Green River. By late March and early April, juvenile chinook (FL = 50 mm) were using areas in the thalweg and associated with scour pools behind boulders and mats of large woody debris. Mean water column velocities in these habitats were less than 2.0 fps (E. Jeanes, R2 Resource Consultants, unpublished data). The Sammamish River lacks this type of habitat because most off-channel habitats in the Sammamish River are no longer available to chinook smolts due to widespread channelization (Jeanes and Hilgert 1999).

In general, upon emergence, chinook follow one of two life history strategies while residing in freshwater as juveniles. Stream-type juveniles reside in streams for a year to eighteen months before moving downstream to saltwater, while ocean-type juveniles migrate to saltwater sometime during their first year (Taylor 1990). Certain gradations or behavioral tendencies within the ocean- and stream-type rearing strategies have also been identified in fall chinook populations (Table 9) (Reimers 1971; Hayman et al. 1996). We found four of the life history phenotypes in the Sammamish River during our study. Chinook alevins were captured in the downstream reaches of the Sammamish River near Kenmore, indicated their tendency to move into Lake Washington at an early developmental stage (Phase I). Chinook fry that were captured and recaptured in the Sammamish River throughout the migration period provide evidence that Phase II chinook are present. The short peak in migration that we found, combined with late emigration from Bear Creek reveal that most of the chinook in the Sammamish River display Phase III traits. And finally, the capture of overyearling chinook in the Sammamish River indicate that a few Phase V chinook (both wild and hatchery) are present.

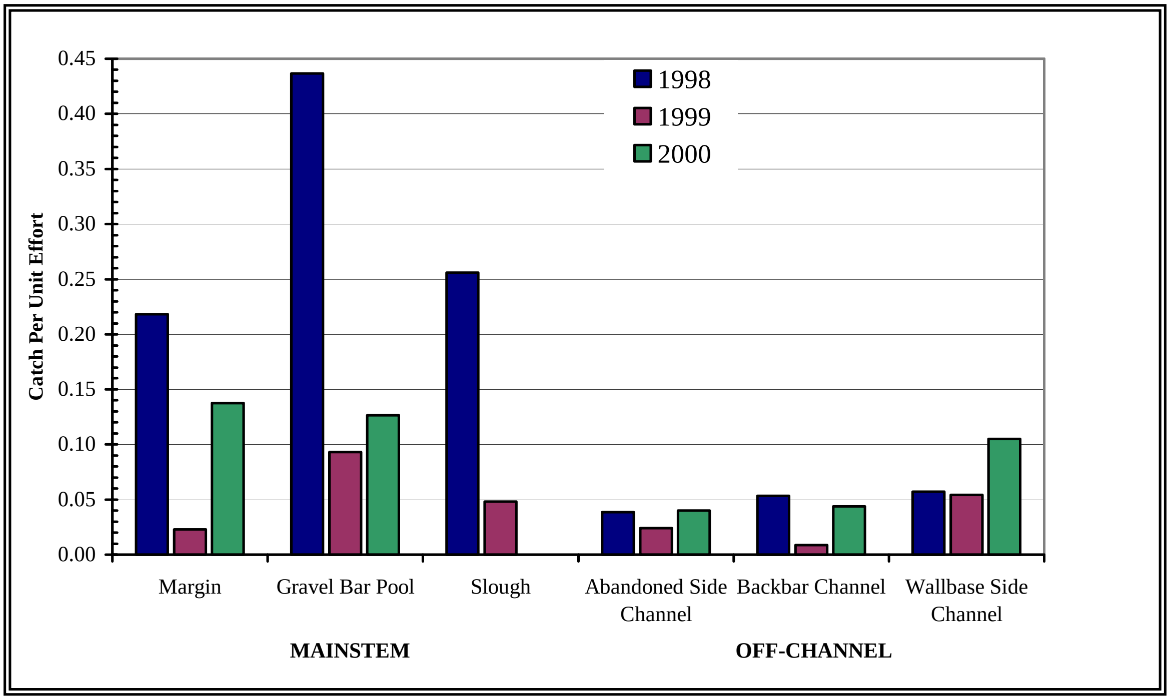

Figure 34. Relative use of mainstem (margin, gravel bar pool, and slough), and off-channel (abandoned side channel, backbar side channel, and wallbase side channel) habitat by juvenile salmonids in the middle Green River, Auburn, Washington, 1998-2000.

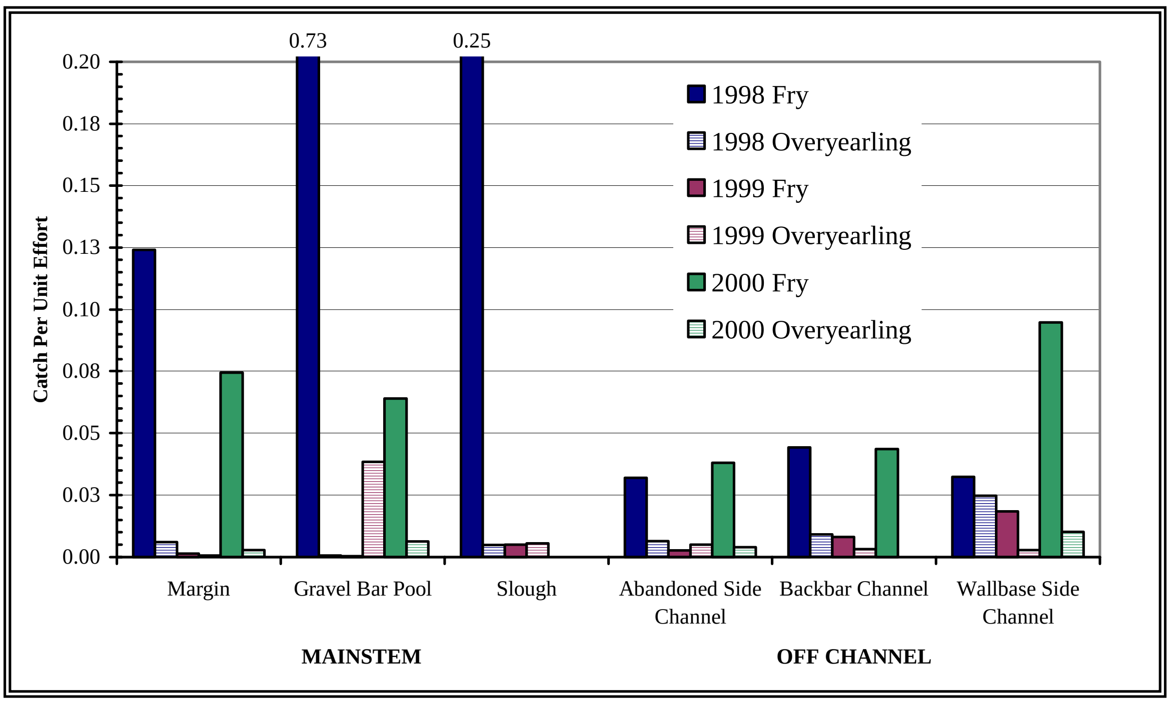

Figure 35. Relative use of mainstem (margin, gravel bar pool, and slough), and off-channel (abandoned side channel, backbar side channel, and wallbase side channel) habitat by age category (fry and overyearling) in middle Green River, Auburn, Washington, 1998-2000.

Juvenile chinook salmon are not the only species known to utilize mainstem rearing/resting habitat. Salmonid fry (chinook, coho, and chum salmon, and rainbow and cutthroat trout) and overyearlings (coho and chinook salmon, and rainbow and cutthroat trout) were commonly captured in mainstem areas of the Green River (Jeanes and Hilgert 2001). The juvenile salmonid catch rate in the Green River was greater in mainstem sites relative to off-channel locations throughout the 1998-2000 study period (Figure 34 and 35).

Table 9. Life history phenotypes identified in juvenile fall chinook salmon in Sixes River, Oregon, and status of life history phenotypes in the Sammamish River (adapted from Reimers 1971).

Life History Category	**Life History Description**	**Status in the Sammamish River**
Phase I	Chinook alevins emerge from the gravel and move immediately downstream to saltwater within two weeks of emergence.	Present
Phase II	Chinook alevins emerge from the gravel and move into lateral rearing habitat of the mainstem (or tributary) until early summer before migrating downstream to the estuary.	Present
Phase III	Chinook alevins emerge from the gravel and move into lateral rearing habitat of the mainstem (or tributary) until late summer before migrating downstream to the estuary.	Present
Phase IV	Chinook alevins emerge from the gravel and stay in the tributary streams (or the mainstem river) until autumn rains before moving downstream.	Unknown
Phase V	Chinook alevins emerge from the gravel and stay in the tributary streams (or the mainstem river) until the next spring and migrate downstream as yearlings.	Present

As chinook fry emerge from the gravel environment they rapidly disperse downstream from the redd. This behavior has been hypothesized as a mechanism to reduce predation and minimize energy expenditures that are needed to adjust population levels to available food and space (Reimers 1971). Generally, this behavior occurs during the night with fry drifting downstream in the current until reaching calm water or until daylight. Passive migration downstream may occur for several days after emergence from the redd, and before fry adopt the social behavior of resident fish (i.e., social interactions) (Reimers 1971). Under this hypothesis, late emerging chinook fry may be selected against, whereby the most productive rearing habitats are already occupied upon their emergence and smaller, less-developed fish, are displaced into unfavorable habitat conditions.

The distribution of juvenile chinook in freshwater is often positively correlated with water depths, and more importantly velocities, in proportion to their body size (Chapman and Bjornn 1969; Lister and Genoe 1970; Reimers 1971; Everest and Chapman 1972; Wright et al. 1973; Don Chapman Consultants 1989; Bjornn and Reiser 1991; Healey 1991; Spence et al. 1996; Cramer et al. 1999). Hayman et al. (1996) and Beamer and Henderson (1998) found that most juvenile chinook in the Skagit River, Washington occupied "near-shore" areas. The authors developed three near-shore strata: 1) bank habitat (vertical or near shore); 2) bar habitat (shallow, low-gradient shore interface); and 3) backwater habitat (enclosed, low-velocity areas separated from the main river channel). Juvenile chinook use of these areas was highest in backwater (0.17 chinook per ft^2) followed by natural banks (0.09 chinook per ft^2) and bar habitat (0.04 chinook per ft^2). Likewise, Murphy et al. (1989) found chinook in the Taku River, Alaska primarily occupied mainstem habitats, rarely using off-channel areas. Diurnal migrations into shallow, slow, sandy mainstem margins is common among larger (>60 mm) chinook fry that occupy deeper and faster daytime habitats (Don Chapman Consultants 1989).

Obviously, juvenile chinook salmon exhibit a range of freshwater life history strategies. These strategies may help the population persist in the face of annual variations in habitat availability in both freshwater and marine environments. The relative contribution of each of the life history strategies to total adult returns is difficult to quantify and may vary from year to year (Reimers 1971). Structural modifications to their habitat will affect each life history strategy differently, thus benefiting one juvenile strategy and harming another (NRC 1996). Unfortunately, the rudimentary understanding of the influence of habitat changes on chinook in general, and in the Sammamish River specifically, limits the ability to accurately predict the consequences of specific enhancement/restoration measures.

We found a mixed response of juvenile salmonids to current enhancement/restoration strategies utilized in the Sammamish River. Juvenile salmonids exhibited a preference for levee setback sites that did not contain large woody debris. Juvenile salmonid use of sites containing large woody debris sites, with and without levee setback, were significantly lower than within the levee setback sites without wood. The gradation between the three restoration/enhancement techniques indicate that the shallow bank angle had a greater influence on juvenile salmonid use than the presence of LWD. Even within the natural stream sections of the Sammamish River, juvenile salmonids were consistently found residing in the portions with the lowest bank angle. Jeanes and Hilgert (1999) found that the majority of the Sammamish River is characterized by very steep cross-sectional profiles

(Figure 36). It appears that juvenile salmonid use of mainstem habitat in the Sammamish River can be enhanced by moving the levee horizontally, thus decreasing the bank angle and providing shallow water nearshore habitat (Figure 37). The addition of large woody debris may enhance the response by juvenile salmonids, however this may not be necessary at every site. This enhancement/restoration technique will also serve to meet the local need for conveyance of flood flows. While we did not detail the response of juvenile salmonids over multiple years or seasons, the information collected from the pilot study conducted in 2000 also indicated that there was a difference in juvenile salmonid use of created habitats in the Sammamish River (Figure 38).

Water temperatures appear to limit the period that juvenile salmonids can safely reside in the Sammamish River beginning in late July. We recorded mean daily water temperatures exceeding 22ºC in the Sammamish River at Marymoor Park during this study and during the pilot study conducted in 2000. Salmonids may have adapted to the elevated water temperatures in the Sammamish River by rearing for extended periods in tributaries and rapidly migrating downstream. We recommend that stream enhancement/restoration activities take advantage of this life history phenotype by concentrating their efforts in areas located immediately downstream from tributary inflow. Tributary inflow areas may also provide for the majority of spawning habitat in the Sammamish River (Jeanes and Hilgert 1999). In this manner, habitat enhancement benefits would be provided to both juvenile salmonids outmigrating from tributaries and salmonids emerging from spawning locations in the Sammamish River.

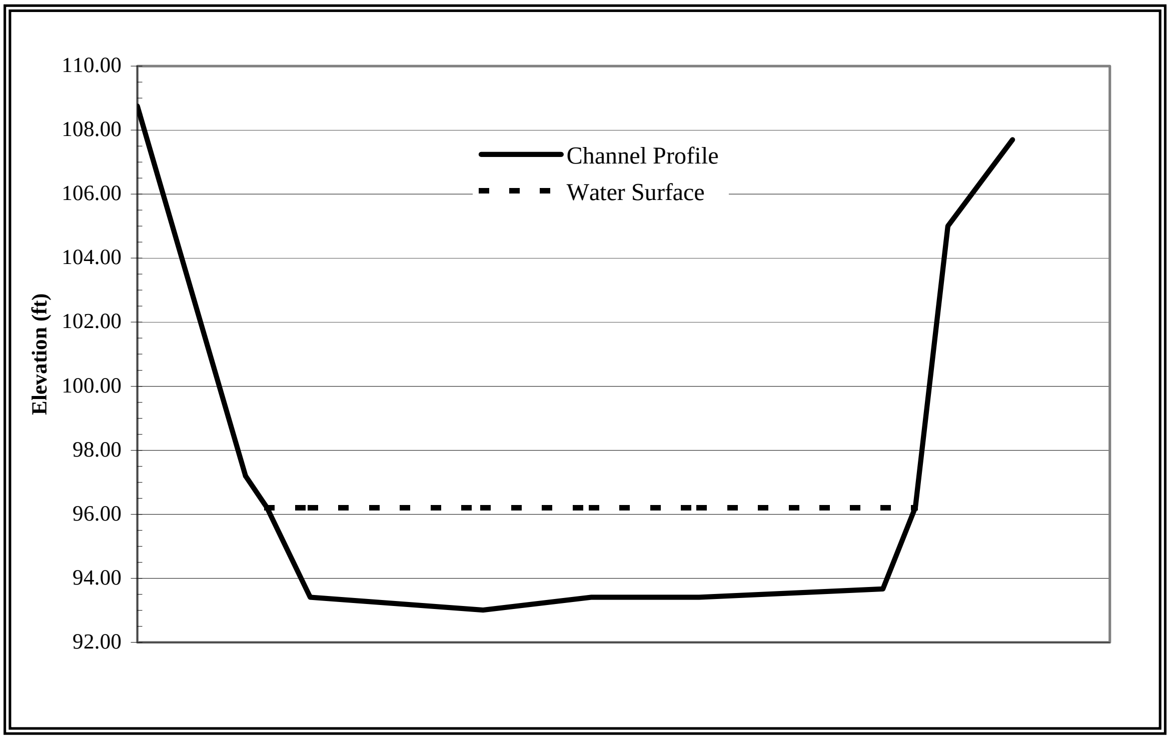

Figure 36. Typical channel profile associated with the Sammamish River, Washington, (adapted from Jeanes and Hilgert 1999).

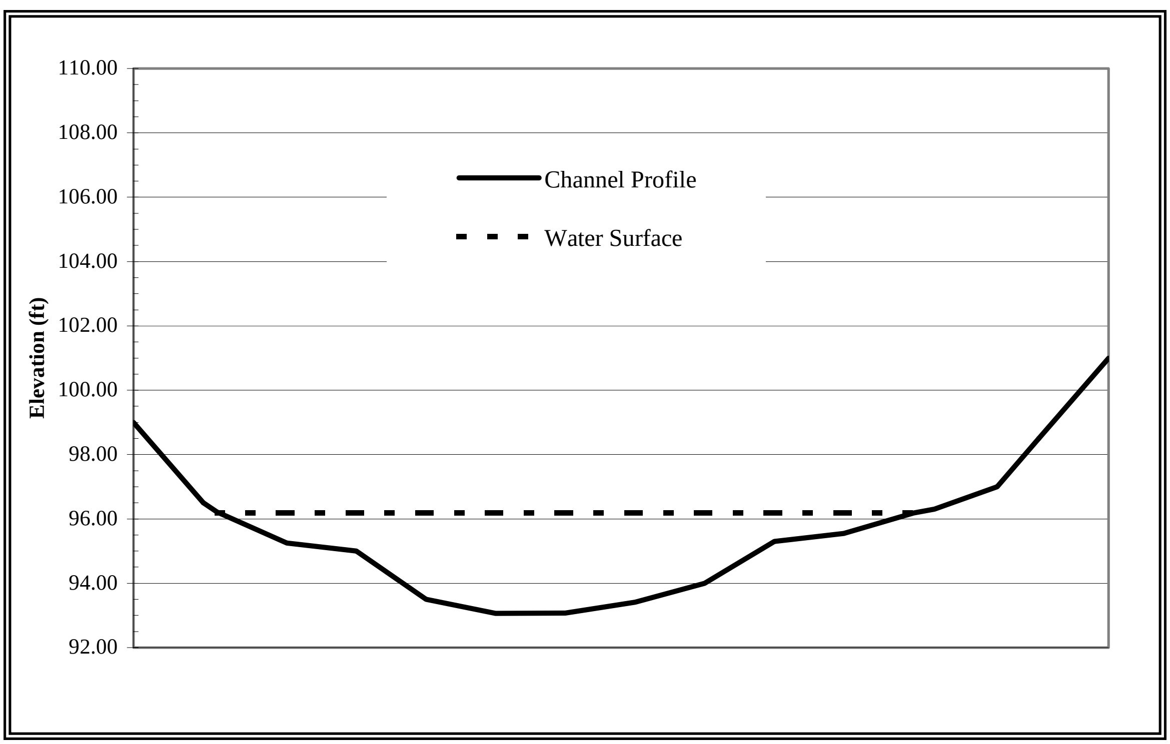

Figure 37. Channel profile associated with hypothetical levee setback site in the Sammamish River, Washington (adapted from Jeanes and Hilgert 1999).

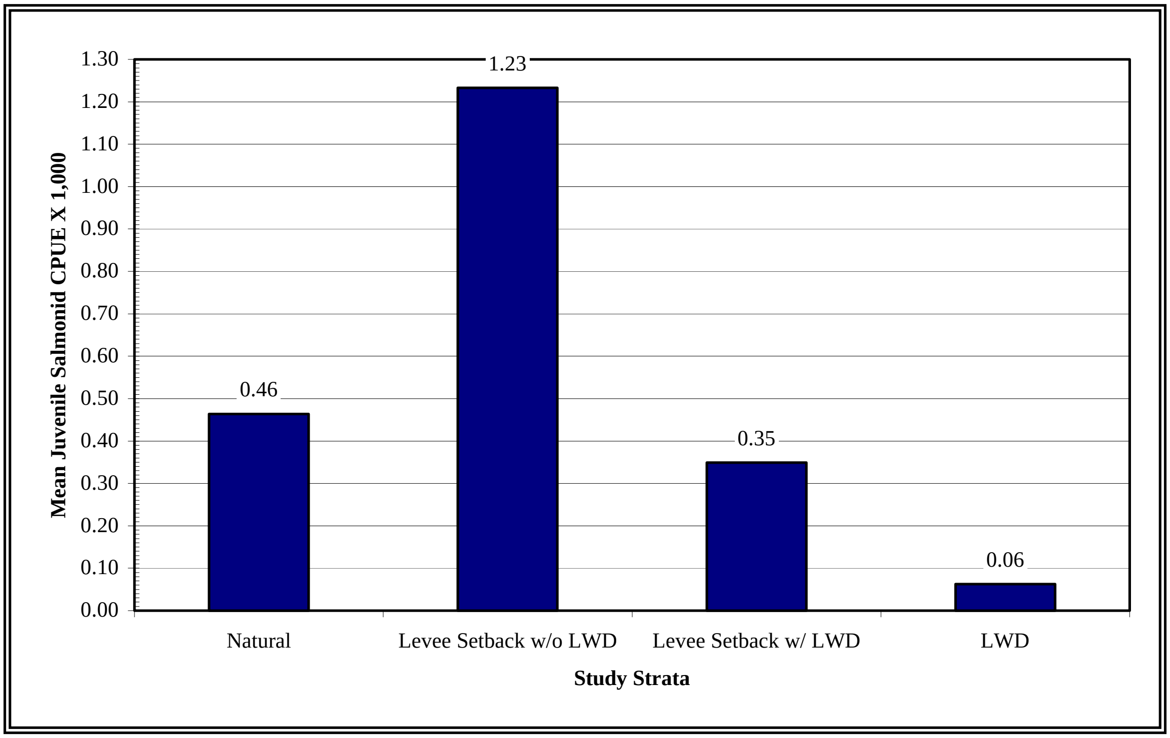

Figure 38. Mean juvenile salmonid catch from study strata during pilot study conducted in the Sammamish River, Washington, 2000.

Finally, this study was developed to evaluate the response of juvenile salmonids to existing stream enhancement/restoration projects that are currently used in the Sammamish River. The response exhibited in the Sammamish River may not be indicative of responses found elsewhere in the Pacific Northwest. The Sammamish River is a relatively large, low gradient river that has virtually no off-channel habitat available for use by juvenile salmonids. The enhancement/restoration techniques used in the Sammamish River are simple to design; anthropogenic constraints on the river corridor often preclude the use of more complicated techniques. While the majority of the river corridor is owned by King County, the Sammamish River Trail, highways, and sewage pipelines border many miles of the river, often on both sides. The riparian canopy communities associated with the Sammamish River are virtually non-existent for large portions of the river (Jeanes and Hilgert 1999). Juvenile salmonid response to large woody debris (< 4 in. diameter) may be strengthened with the addition of small woody debris into the system. Juvenile salmonids have been documented using this type of habitat in the Cedar River (R. Peters, USFWS, pers. comm.) and Green River (Jeanes and Hilgert 2001) in King County. Thus, the influx of small woody debris may be an important habitat component in the Sammamish River system.

An adaptive management approach should be utilized during enhancement/restoration activities occurring on the Sammamish River. Understanding the influence of various life history phases of juvenile salmonids will help evaluate the long-term effects of enhancement measures and help direct management decisions. Enhancement techniques should first be developed and instituted on a small scale (site level) and monitored over several seasons to determine salmonid response before they are instituted throughout the Sammamish River. We have shown the positive response to several techniques and to one life stage over a short period of time. Importantly, the criteria for assessing the success of a restoration effort must be established at the onset of a project. Future monitoring plans could utilize the results from this study to establish criteria for new projects. Not all juvenile salmonids should be expected to respond in the same manner. Juvenile response in this study was mixed between species and age classes. For example, salmon fry did not appear to respond to the deep water habitat (>3.0 ft) created behind instream boulders or at the base of rootwads. However, overyearling trout (cutthroat and rainbow) were often captured in this habitat. This habitat may also provide refugia to adults during their upstream migration. Recognition of this possibility is necessary when establishing objectives and expectations for future enhancement/restoration projects.

6. ACKNOWLEDGEMENTS

We extend our sincere appreciation to the staff of Marymoor State Park and King County Water and Land Resource Division for allowing us entry into sites beyond normal operating hours. Funding for this research was administered by the U.S. Army Corps of Engineers, Seattle District; King County Water and Land Resource Division; and the Cities of Issaquah, Redmond, Woodinville, Bothell, and Kenmore, Washington.

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